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AN ATLAS FOR THE FUTURE NATIONAL PARK
'Las Cumbres de la Sierra de Guadarrama'

Laura Lolo Aira

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UNIVERSIDADE NOVA
UNIVERSITAT JAUME·I
Westfälische Wilhelms-Universität Münster

AN ATLAS FOR THE FUTURE NATIONAL PARK

'LAS CUMBRES DE LA SIERRA DE GUADARRAMA'

Dissertation supervised
by

Roberto Henriques
PhD in Information Management
Instituto Superior de Estatística e Gestão de Informação (ISEGI)
Universidade Nova de Lisboa (UNL)

Edzner Pebesma
PhD in geosciences
Institute for Geoinformatics (IFGI)
Westfälische Wilhelms Universitat-Münster

Joaquín Huerta
PhD in Computer Science
Institute of new imaging technologies (INIT)
Universitat Jaume I (UJI), Castellón

February
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Declaration of originality

This is to certify that the work is entirely my own and not of any other person, unless explicitly acknowledged (including citation of published and unpublished sources).

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Signed: Laura Lolo Aira

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AN ATLAS FOR THE FUTURE NATIONAL PARK

‘LAS CUMBRES DE LA SIERRA DE GUADARRAMA’

ABSTRACT

This research aims to create a digital atlas for the future National Park of ‘*Las Cumbres de la Sierra de Guadarrama’* as a driving tool for knowledge and study of the territory, using a methodology that integrates Information Technologies (IT) such as Geographic Information Systems (GIS) and Internet and the Web technologies, and providing access to geospatial information to the researchers, students and general public interested in the study of this protected area.

The greatest challenge is to develop a database, implemented in a GIS, which enables the integration and processing of large amount of geospatial data that cover the area of interest, allowing for the description of its features, defined by a series of core datasets: administrative boundaries, demography, topography, hydrography, climate, vegetation, geology, land uses, protected areas, urban areas and transport network. However, the heart of the creation of the Atlas is the design and production of the digital cartography, which is essential for the communication and for an effective perception of information.

The visualization of high quality maps, accompanied by text and photographs, through the creation of a digital Atlas embedded in a Web Site, is fundamental to ensure an optimum usability of available geographic information and plays an important role in the process of its dissemination, allowing the user to acquire a wide knowledge of the physical and human environment that characterize the National Park and its surroundings.

In addition, the creation of the atlas and the generated geospatial information intended to be a support for natural environment management and conservation of the National Park, as well as for an efficient planning tool of new activities, favouring the sustainable development in the area.

UN ATLAS PARA EL FUTURO PARQUE NACIONAL

‘LAS CUMBRES DE LA SIERRA DE GUADARRAMA’

ABSTRACT (Spanish)

Esta investigación tiene como objetivo crear un atlas digital para el futuro Parque Nacional de ‘*Las Cumbres de la Sierra de Guadarrama’*, como una herramienta de guía para el conocimiento y estudio del territorio, utilizando una metodología que integre Tecnologías de la Información (TI), como los Sistemas de Información Geográfica (SIG) e Internet y las tecnologías Web, y proporcionado el acceso a la información geográfica a investigadores, estudiantes y al público interesado en el estudio de esta área protegida.

El mayor desafío es desarrollar una base de datos, implementada en un SIG, que posibilite la integración y procesamiento de gran cantidad de datos geoespaciales que cubren el área de interés, permitiendo la descripción de sus características, definidas por una serie de conjuntos de datos principales: límites administrativos, demografía, topografía, hidrografía, clima, vegetación, geología, usos del suelo, áreas protegidas, áreas urbanas y red de transportes. Sin embargo, el corazón de la creación del Atlas es el diseño y la producción de la cartografía digital, que es esencial para la comunicación y para una efectiva percepción de la información.

La visualización de los mapas de alta calidad, acompañados de texto y fotografías, mediante la creación de un Atlas digital embebido en un Sitio Web, es fundamental para garantizar un óptimo uso de la información geográfica disponible y juega un importante rol en su proceso de difusión, permitiendo al usuario adquirir un amplio conocimiento del medio físico y humano que caracteriza el Parque Nacional.

Además, la creación del Atlas y la información geoespacial generada pretende ser una herramienta de apoyo para la conservación y gestión del medio ambiente natural del Parque Nacional, así como para una eficiente herramienta de planificación de nuevas actividades, favoreciendo el desarrollo sostenible en el área.

KEYWORDS

Atlas

Geographical Information Systems

Geospatial Technologies

GIS Database

National Park

Website

KEYWORDS (In Spanish)

Atlas

Sistemas de Información Geográfica

Tecnologías Geoespaciales

Base de datos SIG

Parque Nacional

Sitio Web

ACRONYMS

ASCII – American Standard Code for Information Interchange

CORINE – Coordination of Information on the Environment

CRS – Coordinate Reference System

DEM – Digital Elevation Model

ECW – Enhanced Compression Wavelet

ED50 – European Datum 1950

ESRI – Environmental Systems Research Institute

ETRS89 – European Terrestrial Reference System 1989

GI – Geographic Information

GIS – Geographic Information System

HTML – Hypertext Markup Language

IT – Information Technology

LIDAR – Light Detection and Ranging, Laser Scanning

PNG – Portable Network Graphics

SDI– Spatial Data Infrastructure

UNESCO – United Nations Educational, Scientific and Cultural Organization

UTM – Universal Transversal Mercator

WWW – World Wide Web

TABLE OF CONTENTS

INDEX OF TABLES

INDEX OF FIGURES

1. INTRODUCTION

The creation of the Atlas is born with the idea of making known the natural values of the National Park '*Las Cumbres de la Sierra de Guadarrama'* and its surroundings.

1.1 THEORETICAL FRAMEWORK

The natural environment is one of the main sources of wealth of a country, so proper management and conservation is essential to ensure quality of life and development of its people.

Protected Natural Areas have among their main objectives the conservation of the natural resources, favouring the socio-economic development of the territory, which is part of the enjoyment of their natural and landscape values by the society, and becoming a living observatory for research[1].

Their statement ensures the conservation of the natural, cultural, landscape and scientific values recognized by society and supported on a legal norm. Thus, the National Park figure is defined in Law 5/2007, April 3 of the Network of National Parks, as '*the natural space of great ecological and cultural value, little changed from the exploitation or human activity, than in reason of the beauty of its landscapes, the representativeness of its ecosystems or the uniqueness of its flora, its fauna, its geology or geomorphological formations, has some ecological, landscape, cultural and educational values prominent scientists whose conservation deserves preferential treatment and is stated of general interest to the State'*.

1.1.1 Geographic Information Systems (GIS) and Internet

The usage of the geospatial technologies enables the detailed study of the territory framed within the National Park and its surroundings. Geographic Information Systems (GIS), through the various tools available facilitate the integration and the analysis of large amounts of geospatial data and the creation of maps that describe and allow knowing the physical and human environment of this area.

[1] Law 42/2007 of December 13, Natural Heritage and Biodiversity.

Since Geographic Information Systems (GIS) were originated and developed between 1960s and 1970s, it has made enormous progress. In the 1980s, with advances in computer technology and the theory of spatial data processing and analysis, GIS enabled both computer cartography and spatial data analysis to be integrated within one same computational framework.

During the 1990s, the power of personal computers led GIS to becoming an application that could be implemented on a variety of platforms and operating systems. Both computer graphics and graphical user interfaces were greatly improved, and spatial database management systems were more robust and stable (Yang, C. et al, 2011).

Therefore, the development in various fields of computing has benefited GIS, thanks to the improvement of databases facilitating the management of vast amounts of information that is referenced to digital maps; computer graphics techniques that provide better data models for storage, retrieval and display of geographic objects; and advanced visualization techniques let us to create elegant representations of territory.

In the 1990s, the Internet and Web technology changed the GIS development allowing access geospatial information and resources through a Web browser.

From the beginning of the twenty first century, technological advancements in GIS and other geospatial data management tools, along with the development and popularization of the World Wide Web, have contributed to the creation of many geospatial portals containing global and regional spatial databases and web map services, favouring distribution and access to an enormous volume of geospatial data and datasets. Organizations from around the world collaborate for create Spatial Data Infrastructures (SDI) that supports the publishing of digital geographic information on the Internet.

'*The rapid evolution of information science and technologies not only enhance our ability to collect, archive, and process spatial data more efficiently, but also to generate and utilize geographic information and knowledge more efficiently than what we could do in the past*' (Yang et al., 2011).

1.1.2 Toward cartographic visualization: Atlas on the World Wide Web

For centuries, the systematic and coherent collection of maps in book form, recognized as atlas, has allowed for the knowledge of a particular territory. The maps are models of the real world and the main method of identifying and representing the location of geographic features on the landscape.

Atlases are one of the better known cartographic products (Kraak, 2001) since the cartographer Gerhardus Mercator released *'The World Atlas'* in 1595. They can be understood as a collection of maps with a specific purpose and organized in form of a book, which usually includes tables, graphs and text.

Alonso (1968) defined atlases as: **'***To the layman, any book consisting mainly of maps is an atlas, but technically to the geographer, no cased collection of maps deserves the name unless it be comprehensive in its field, systematically arranged, authoritatively edited and presented in a unified format*.'

Cartography, which is defined as the art and science of making maps, is thousands of years old. However in the last several decades has undergone enormous changes as a result of digital technologies.

The study of contemporary atlases involves two distinctive transitions: from paper to digital and from discrete to networked (Da Silva and Cartwright, 2006).

Historically, atlases were generated manually, but today, due to advances in technology, the way to produce and distribute cartographic products has changed. Manual techniques, that was once the basis of cartographic design and production, have now been completely replaced by digital workflows from 1980s, allowing better management, faster retrieval and improved presentation of data. Electronic devices, especially computers, have gone from being a tool to a medium for cartography.

Siekierska and Taylor (1991) defined the digital atlas as: '*The electronic atlas is a new form of cartographic presentation and can be defined as an atlas developed for use primarily on electronic media*'.

The rise of the Internet as a medium for cartography in the mid-nineties changed the way to produce and distribute atlases in digital format: from discrete storage (produced for distribution in floppy disks, CD-Rom or DVD) to the World Wide Web (WWW).

WWW, which was developed by Tim Berners-Lee in 1991, is a hypertext-based system that operates over the internet and constitutes a vast collection of electronic documents each one composed of a linked set of pages written in HTML language. The documents are stored in files on many thousands of computers that are distributed around the global Internet, allowing information to be disseminated with speed and accuracy.

Internet has become an important medium for dissemination of maps and geospatial data, allowing to an unlimited number of users the access to information anywhere at all times. Every day, millions of people access to Geographic Information (GI) via the Internet and millions of maps are exchanged every day on the Internet. GI accessible through the WWW, includes from maps that are read as a paper map to sophisticated applications that are used to build queries by submitting requests to the Web map services that are even capable of performing spatial analysis and processing.

The process of designing, implementing, generating and delivering maps on the World Wide Web is called Web mapping. While the first maps were primarily static, today web maps can be fully interactive and are able to integrate multiple media (Neumann, A., 2012).

"Digital Multimedia is considered to be any combination of two or more media, represented in a digital form, sufficiently well integrated to be presented via single interface, or manipulated by a single computer program." (Chapman et al., 2000).

Multimedia technology encompasses various types of data, such as text, graphics, hyperlinks, images, sound, digital and analogue video and animation; and presents them in an integrated form. The combination of several media often results in a powerful presentation of information and ideas to stimulate interest and enhance information retention.

1.1 OBJECTIVES

The main objective of this research is to create a digital Atlas for the future National Park of '*Las Cumbres de la Sierra de Guadarrama'* as a driving tool for knowledge and study of the territory, providing access to geospatial information to researchers, students and general public interested in this protected area.

This main objective can be broken down into other, more specific, which express a higher level of detail:

- To collect and systematize the necessary mapping information and determine the technical requirements leading to the design and creation of the Atlas.
- To develop and manage a database, implemented in a GIS, that contains the spatial data required to identify the features of the territory, allowing for their processing and analysis and the generation of new information to prepare the digital cartography.
- To represent the analysed geographic information, by the building of digital thematic cartography about the different elements that characterize the physical and human environment of the study area.
- To design and produce a multimedia website that provides the access and the visualization of the geographic and environmental information referred to the National Park and its surroundings, for its use on computers.

1.3 GENERAL METHODOLOGY

The following steps describe the proposed methodology for achieving each one of the mentioned objectives:

A. Collection and compilation of geographic information from different sources.

B. Selection and classification of acquired spatial information through the elaboration of an inventory.

C. Development and management of the GIS database, by the integration of spatial data obtained from existing data sources, and organization and structuration of GI highlighting core datasets that describe the features of the territory: administrative boundaries, topography, hydrography, climate, vegetation, geology, land uses, protected areas, demography, urban areas and transport network.

E. Exploration and analyses of the spatial information contained in the GIS database and generation of new information derived.

F. Building and design of thematic maps, representing of analysed geographic information and showing the physical and human environmental presence in the area.

H. Design and creation of the Website in HTML format showing the results of the analysis and providing the public access and visualization of the geographic information included in the Atlas.

In the figure 1, the phases to the building of the Atlas are detailed:

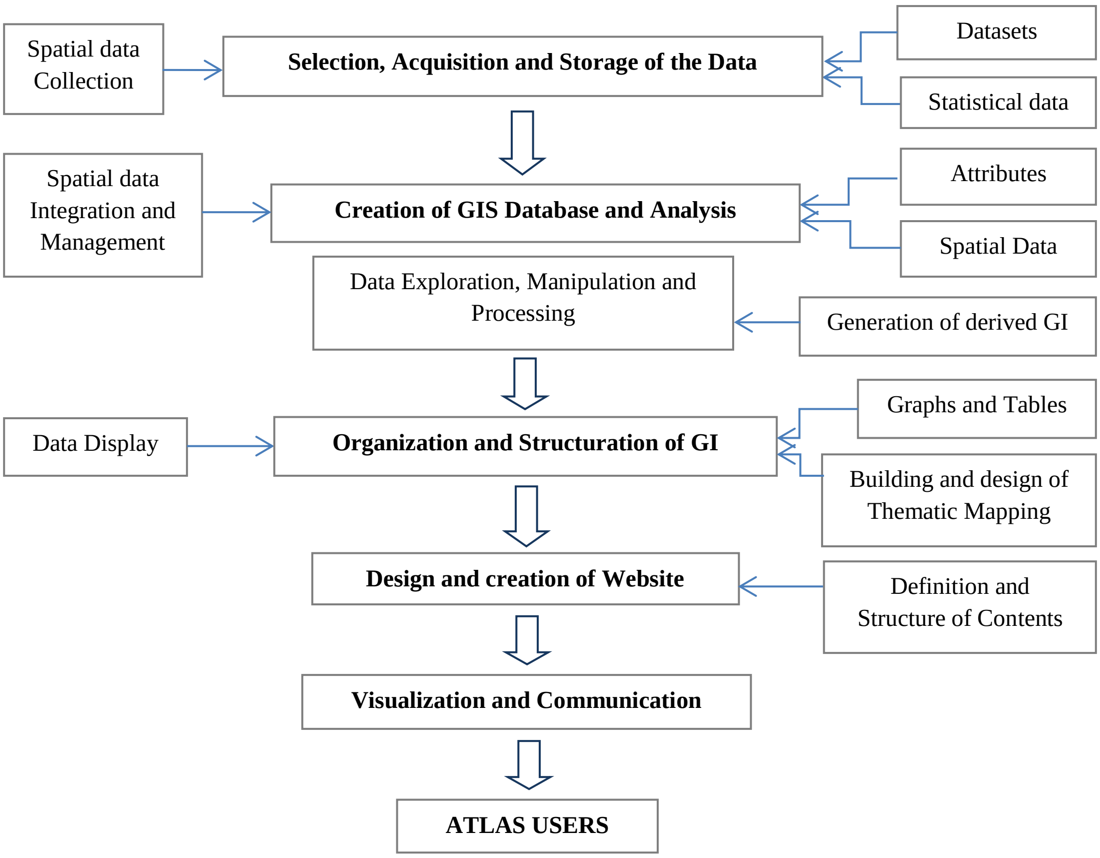


Figure 1. Atlas Building Diagram.

1.4 DISSERTATION ORGANIZATION

This dissertation is organized into six chapters. The first two chapters cover the introductory content of the thesis. The objectives and the general methodology of the research, as well as the theoretical framework which is divided in two epigraphs: '*Geographic Information System (GIS) and Internet*' and '*Toward, cartographic visualization: Atlas on the World Wide Web'*; are described in the first chapter. In the second chapter, the study area is located geographically and administratively and framed within a geographic context at national level.

Chapter 3 entitled '*An underlying GIS database*' describes the procedures followed for the development of the GIS database and the processing and analysis of the geographic data contained therein. The foundation for the building of cartography and the design and making of the Atlas are described in Chapter 4 '*Cartographic design: Basis for the mapping preparation*' and Chapter 5 '*Visualization the geographic information: design and making of the Atlas over the Internet*'.

The sixth chapter includes the content of the Atlas '*The Atlas of the National Park* ***Las Cumbres de la Sierra de Guadarrama***', which is divided into two blocks: physical environment and human environment. And finally, the last chapter presents the conclusions resulting from the elaboration of this research.

2. GEOGRAPHIC CONTEXT: STUDY AREA

Located in Spain, the National Park '*Las Cumbres de la Sierra de Guadarrama*' is geographically situated between latitudes 40º 42' and 41º 6' N and between longitudes 4º 13' and 3º 41' W. Administratively, it is situated between the provinces of *Madrid* and *Segovia*, belonging to the Autonomous Communities of *Madrid* and *Castilla y León* respectively (figure 2).

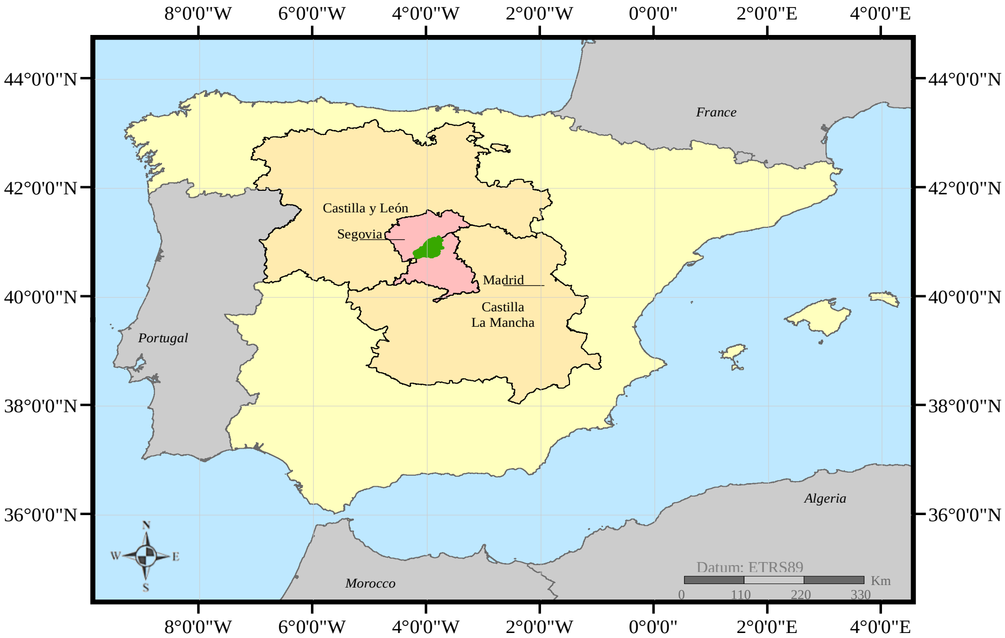


Figure 2. Map of situation of the National Park between the provinces of *Madrid* and *Segovia*.

The National Park '*Las Cumbres de la Sierra de Guadarrama'* is integrated within the National Parks Network that constitutes a set of protected areas that represent the best models of the Spanish natural heritage (figure 4). Since the National Park '*Picos de Europa'* was established in 1918, until 2007, with the declaration of National Park '*Monfragüe'*, fourteen protected areas have been declared under the statutory protection of National Park. The National Park *'Las Cumbres de la Sierra de Guadarrama'* is the fifth one created in Spain, protecting 337 square kilometres, 217 sq.km belonging to the province of *Madrid* and 120 sq.km belonging to the province of *Segovia*, which places it in the fourth place in terms of extension of existing Spanish National Parks.

Its Peripheral Protection Area, designed to prevent and avoid landscape and ecological impacts from outside[2], covers 629 square kilometres, not including the urban areas. In total, the study area surface covers 966 squares kilometres (table 1 and figure 3).

Area (sq.km)	Madrid	Segovia	Total
National Park	217	120	337
Peripheral Protection Area	300	329	629
Total	517	449	966

Table 1. Areas cover by the National Park and its surroundings.

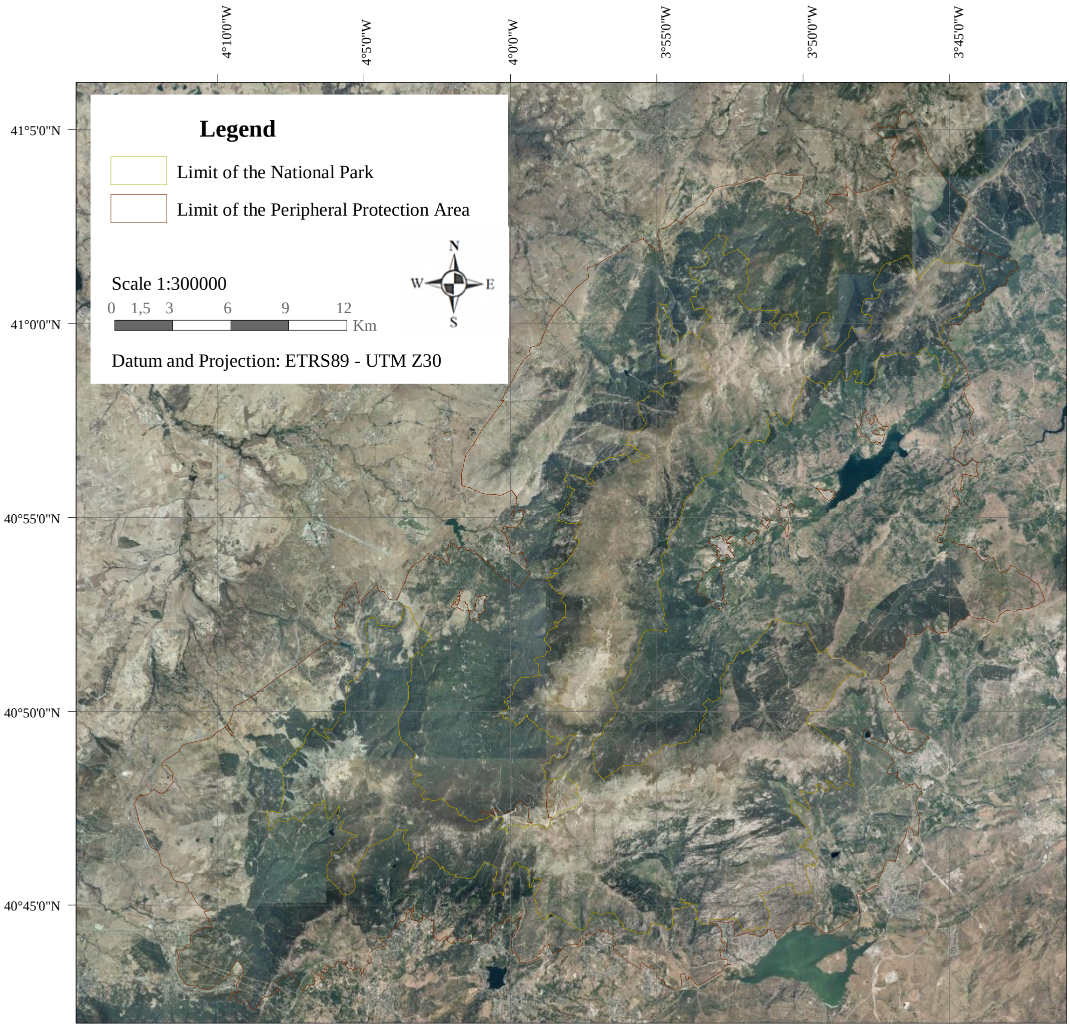


Figure 3. Map of situation and limits of the National Park and its Peripheral Protection Area.

[2] Law 9/1999, of May 26, Conservation of Nature.

Figure 4. Map of the Network of Spanish National Parks.

3. AN UNDERLYING GIS DATABASE

3.1 OVERVIEW

A **Geographic Information System** (GIS) is a computerized system designed to deal with the collection, storage, manipulation, analysis, visualization and display of Geographic Information. Arnoff in 1989 defined GIS as '*a computer based system that provides four sets of capabilities to handle geo-referenced data: data input, data management (data storage and retrieval), manipulation and analysis and data output*'.

Data that describe a part of the Earth's surface or the features found thereon could be described as geographic or 'spatial' data (Guo, 2009). They are referenced to known locations on the Earth's surface, i.e. they are 'georeferenced' by a Coordinate Reference System (CRS).

Geographic data are organized into different 'thematic' **layers** (figure 5), one for each set of defined features or phenomena being recorded, making data management, manipulation and analysis more effective.

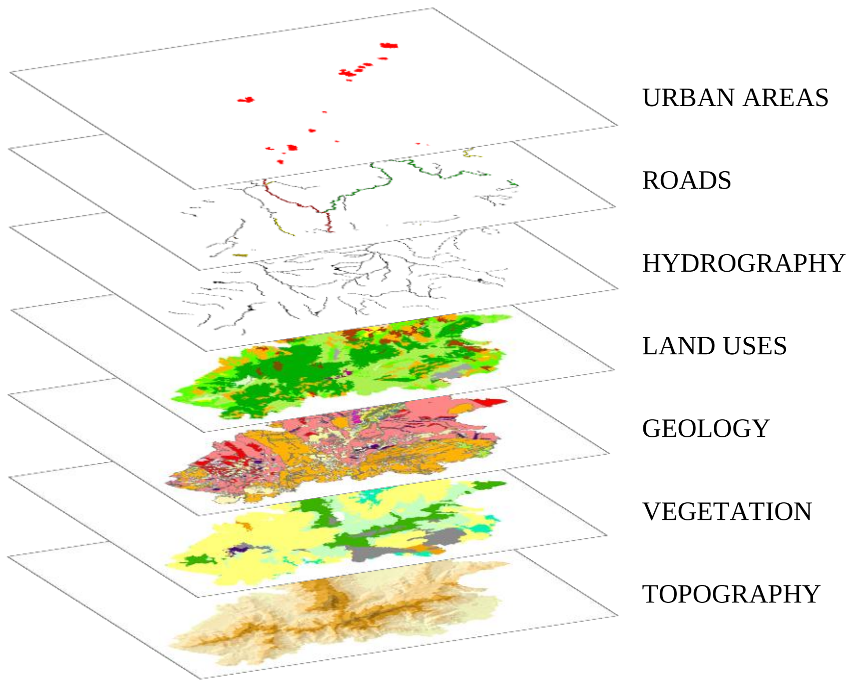


Figure 5. Thematic layers - space as an indexing System.

GIS database consists of a set of layers that provide the context for the creation of the Atlas. It is a computer-based representation of the real world that contains information about the location of the objects and the characteristics thereof, leading to answers questions about *where* things are or about *what* is located at a given location.

The extensive GIS database created allows for the description of every feature of the territory included within the study area: topography, hydrography, climate, vegetation, geology, land uses, protected natural areas, demography, urban areas and transport network; by geographic data integration and processed using Geographic Information Systems (GIS).

3.2 SOFTWARE

The database has been implemented using the commercial software **ARCGIS 10.00**, created by ESRI (Environmental Systems Research Institute), which consists of four applications (ArcCatalog, ArcMap, ArcScene and ArcGlobe), and which have the capabilities that are adapted to the demands of the research, considering, in particular: support for the formats in which information is presented, analytical skills appropriate to the aims pursued and appropriateness of graphical outputs of the system. It is used for treating digital spatial coverage, both vector and raster, although it was developed with a strong vectorial approach.

3.3 GEODETIC DATUM, MAP PROJECTION AND SCALE

The **geodetic reference system** employed for the representation of the territory is the European Terrestrial Reference System 1989 (ETRS89) (table 2), which is the official system adopted in Spain for geographic referencing and mapping in the area of the Iberian Peninsula and *Islas Baleares*[3].

The **cartographic projection** adopted is the Universal Transverse Mercator (UTM), in which the earth is divided into 60 longitudinal zones called UTM zone, of 6°

[3] Royal Decree 1071/2007 of 27 July, which regulates the official geodetic reference system in Spain.

longitude wide each, numbering from the 180º W meridian and increasing towards the 180º E meridian. The UTM zone for the National Park is the 30, located between the meridians 0º and 6º W.

The GIS database design, whose primary function is to manage and analyse the Core Datasets defined, is implemented to a sub-regional **scale** (target at 1: 250000 scale).

3.4 GIS DATA COLLECTION: GETTING THE DATA RIGHT

To obtain and acquire the geographic information required for the development of the GIS database and, consequently, for the creation of the Atlas, a large amount of existing digital maps and datasets have been identified, consulted, analysed and selected.

Digital maps have the advantage that they can be more easily manipulated and adapted for the purposes of mapping, and have increasingly become available from many sources.

3.5.2 Sources and Responsible for the Information

The creation of the GIS database is based on the conversion and integration of existing digital databases, such as digital maps in different exchange formats, which are openly available from a wide range of government agencies.

The digital cartography and geospatial datasets are obtained from the following government agencies (table 3):

- Autonomous Agency of National Parks (OAPN), public entity under the Ministry of Agriculture, Food, and Environment (MAGRAMA). The dataset corresponding to the boundaries of the National Park and the Peripheral Protection Area has been obtained from this Agency.

- Spatial Data Infrastructure (SDI) from the Ministry of Agriculture, Food and Environment of Spain (MAGRAMA) (points 2-7 and 11-15):

- Natura 2000 is the European ecological network of conservation areas of biodiversity. The Habitats Directive 92/43/EEC requires all Member States of the European Union to deliver a National List of Sites of Community Importance (LICs) and Special Protection Areas for Birds (SPAs) to shape the Natura 2000 Network (point 4).

- Protected Natural Areas (PNA) dataset contain information about the areas included under one of the five legal protection status: Parks, Nature Reserves, Marine Protected Areas, Protected Landscapes and Natural Monuments; declared by the various Autonomous Communities under the Law 42/2007 of December 13, of Natural Heritage and Biodiversity (Before Law 4/89 of March 27, Conservation of Nature) (point 5).

- The Series Vegetation Map was developed by Salvador Rivas Martínez from the review of the Vegetation Map of Luis Ceballos (1941). This work was done by synthesis in 1981 and revised in 1987. It delimits the areas of the recognized series in a map at 1:400000 scale, in order to make known the great diversity of plant ecosystems of Spain (point 11).

- Andradre Allúe developed a phytoclimatic classification for Spain, the result of which was the characterization of 19 subtypes of vegetation, each one associated to specific climatic characteristics, which met into four types: Arid, Mediterranean, Nemoral and Oroborealioide (point 12).

- The Second National Forest Inventory (IFN2) is a project from the Forest Inventory Service developed between 1986 and 1996. It is part of the National Forest Inventory that reviews the status of national forest land every ten years (point 13).

- The Forest Map of Spain (MFE200) at 1:200000 scale was started in 1985. It contains more than 5,500 species including trees, shrubs and herbaceous plant and is the main layer to the representation of vegetation in Spain (point 14).

- The Inventory of Habitats of Community Interest is a dataset about habitats that was adapted to Spanish territory according to Annex I of Habitat Directive 92/43/EEC (point 15).

- The Information System of Continuous Geological Mapping (SIGECO) is developed by the Geological Institute of Spain (IGME), under the Ministry of Economy and Competitiveness (MINECO):

- It supplies information reflected in the GEODE Plan, which constitutes the support for the generation of a Continuous Geological Map at 1:50000 scale, using as the reference the National Geological Map (MAGNA) (point 16).

- The Download National Center, belongs to the National Geographic Information Center (CNIG), an autonomous body of Spain belonging to the Central Government and established in 1989, under the Ministry of Development (MF) through the Directorate General of the National Geographic Institute of Spain (IGNE) (points 1, 8-10 and 17-19).

  - The National Air Orthophotography Plan (PNOA) aims to obtain digital aerial orthophotos with 25 or 50 cm of resolution and high precision Digital Elevation Models (DEM) throughout the Spanish territory, with an update period of 2 or three years, depending on the area. Two of the products offered are Orthophoto Mosaics and Digital Terrain Models (DTM) with 5 m of resolution, created by interpolation from LIDAR data (points 8 and 19).

    Project management is taken over by the Ministry of Development, through the Directorate General of the National Geographic Institute (IGN) and the National Centre for Geographic Information (CNIG).

  - The National Cartographic Base (BCN200) is a set of geographic data obtained by scanning and digitizing of information originally contained in the series of provincial maps at 1:200000 scale, and subsequently enriched and updated by generalizing of the data contained into the National Cartographic Base at 1:25000 scale (BCN25). It conducted to support national projects like the National Geographic Information System (SIGNA) and Spatial Data Infrastructure of Spain (IDEE), and internationally as EuroRegionalMap (ERM) (point 9).

  - Land Cover Map of Spain, corresponding to the CORINE Land Cover Project, includes versions 1990, 2000 and 2006. The CORINE Land Cover (CLC) has been the responsibility of the European Environment Agency (EEA) since 1995 and was founded with the objective of obtaining a European database of land use (point 17).

  - The CartoCiudad project is the result of the integration and harmonization of data from different state agencies (General Directorate of Cadastre, National Institute of Statistics, State Society Post Office and National Geographic Institute) and autonomous public bodies, resulting in system geographic information about urban and interurban road network. It also incorporates urban maps and census information and post codes of all municipalities in Spain (point 18).

- The website of the National Statistics Institute of Spain (INE), that provides the statistical data for the analysis of demographic characteristics.

- Finally, State Weather Agency (AEMET), that provides climate data about temperature and rainfall.

3.5.3 Synthesis of Geographic Information

The collected geographic information and integrated in the GIS database is detailed in the inventory included in Table 2. This consist of the limits of the National Park and the Peripheral Protection Area; administrative boundaries (municipalities, provinces and autonomous regions) and livestock and agricultural regions; protected natural areas and areas belong to the Natura 2000 Network; Digital Terrain Model (DTM), contour lines and hydrography network; vegetation and habitats, forest and climatic regions; geology; land uses; urban areas; transport network; and finally, orthophotos.

When maps are procured from external sources it is necessary to consult the extensive documentation which is provided together with the datasets for its incorporation in the GIS database and subsequent processing. Without metadata, which describe the type of information contained in the datasets, it is difficult to work with the digital information. For instance, it is not possible to determine the geographic referencing information, including map scale, projection and geographic datum, date of creation, compiling agency and complete legend.

	Name	Scope	Scale/Res.	CRS	Geometry	Type	Extens.	Date
Limit of the National Park		Regional	-	ETRS89	Polygon	Vectorial	(.shp)	Nov 2012
Limit of Peripheral Protection Zone of Park		Regional	-	ETRS89	Polygon	Vectorial	(.shp)	Nov 2012
ADMINISTRATIVE BOUNDARIES								
1	Municipalities, Provinces and Autonomous Communities	National	1:50000	ETRS89	Polygon	Vectorial	(.shp)	March 2012
2	Livestock Regions/Agricultural Regions	National	1:25000	ED50	Polygon	Vectorial	(.shp)	2011/ 2007
3	Database of Global Administrative Areas (GADMIN)	World	-	WGS89	Polygon	Vectorial	(.shp)	2012
PROTECTED NATURAL AREAS								
4	Natura 2000 Network: Special Protection Areas for birds (SPAs) and Sites of Community Interest (LICS)	National	1:50000	ETRS89	Polygon	Vectorial	(.shp)	Sept 2011
5	Protected Natural Areas of Spain: Parks, Nature Reserves, Natural Monuments, Protected Landscapes and other legal status.	National	1:50000	ETRS89	Polygon	Vectorial	(.shp)	Dec 2011
6	Spanish Inventory of Wetlands (IEZH)	National	1:50000	ETRS89	Polygon	Vectorial	(.shp)	April 2011
7	Biosphere Reserves (MaB)	National	1:50000	ETRS89	Polygon	Vectorial	(.shp)	2009
RELIEF, TOPOGRAPHY, HIDROGRAPHY AND ROAD NETWORK								
8	Digital Terrain Model (DTM) Lidar	National	5 m	ETRS89	Cell	Raster	(.asc)	2010
9	National Cartographic Base (BCN200 y BCN25)	National	1:200000 1:50000	ETRS89	Point, Polyline Polygone	Vectorial	(.shp)	July 2010
10	Grid cells of BCN25	National	1:50000	ETRS89	Polygone	Vectorial	(.shp)	2011
VEGETATION AND FOREST								
11	Vegetation Map: Series and storeys of potential vegetation	National	1:400000	ED50	Polygon	Vectorial	(.shp)	1987
12	Phytoclimatic Subregions	National	1:1000000	ED50	Polygon	Vectorial	(.shp)	1990
13	Second National Forest Inventory (IFN2)	National	1:50.000	ED50	Polygon	Vectorial	(.shp)	1986-1996
14	Forest Map of Spain (MFE200)	National	1:200000	ED50	Polygon	Vectorial	(.shp)	1986-1997
15	Habitats	National	1:50000	ED50	Polygon	Vectorial	(.shp)	1997
GEOLOGY								
16	Continuous Geological Mapping (GEODE)	National	1:50000	ED50	Polygon	Vectorial	(.shp)	2005-2011
LAND USES								
17	Corine Land Cover 1990 (CLC90) and 2006 (CLC06)	European	1:100000	ETRS89	Polygon	Vectorial	(.shp)	2006
URBAN AREAS								
18	CARTOCIUDAD: urban and interurban road network	National	1:25000	ETRS89	Polygon,Polyline	Vectorial	(.shp)	2009
ORTHOPHOTOS								
19	Mosaic Orthophotos (PNOA)	National	1:50000	ETRS89	Cell	Raster	(.ecw)	Sept 2012

Table 2. Inventory of Geographic Information Collected and Integrated in the GIS database.

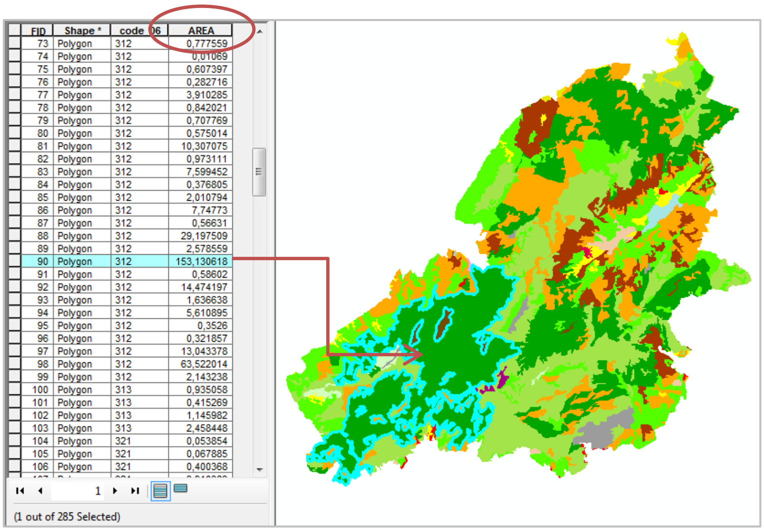
3.5 STRUCTURE OF GIS DATABASE: SPATIAL DATA AND ATTRIBUTES

Before starting the elaboration of the maps, it is necessary to design the structure of all core datasets with the purpose of determining how data are organized. Defining a clean database structure is not a trivial task. Within this framework, data are divided logically into two categories: geometric data and attribute data (Annexe 1). The GIS database stores both categories of data in a file in tabular form.

The GIS database consists, therefore, of the following components:

- The spatial objects database, containing the entities;
- And the geographic attributes table. This file contains one record and one unique identifier for each entity, and the alphanumeric data, such as the values of variables that they describe, like for example, the area measured in square kilometres.

The figure 6 illustrates how the spatial objects database and their attributes table are linked internally, representing a dataset. What makes GIS different from other kinds of computer systems is that these two kinds of information are always connected and are processed together.



FID	Shape *	code 06	AREA
73	Polygon	312	0,777559
74	Polygon	312	0,01069
75	Polygon	312	0,607397
76	Polygon	312	0,282716
77	Polygon	312	3,910285
78	Polygon	312	0,842021
79	Polygon	312	0,707769
80	Polygon	312	0,575014
81	Polygon	312	10,307075
82	Polygon	312	0,973111
83	Polygon	312	7,599452
84	Polygon	312	0,376805
85	Polygon	312	2,010794
86	Polygon	312	7,74773
87	Polygon	312	0,56631
88	Polygon	312	29,197509
89	Polygon	312	2,578559
90	Polygon	312	153,130618
91	Polygon	312	0,58602
92	Polygon	312	14,474197
93	Polygon	312	1,636638
94	Polygon	312	5,610895
95	Polygon	312	0,3526
96	Polygon	312	0,321857
97	Polygon	312	13,043378
98	Polygon	312	63,522014
99	Polygon	312	2,143238
100	Polygon	313	0,935058
101	Polygon	313	0,415269
102	Polygon	313	1,145982
103	Polygon	313	2,458448
104	Polygon	321	0,053854
105	Polygon	321	0,067885
106	Polygon	321	0,400368

Figure 6. Components of the digital spatial database

Non-spatial attributes are input, by conversion from Microsoft Excel spread sheets (.xls) or other database format like Microsoft Office Access (.mdb), and linked the spatial data by means of joining operations through unique identifiers of spatial objects. It is the case, for example, of the attribute data that describes the demographic characteristics (total population and population density) or the climate (temperature and rainfall).

- **Spatial Data and Geometry**

The two fundamental ways of representing spatial information in the GIS database are vector and raster data model. The types of geometry adopted for representing the spatial objects that are utilized are described in the tables included into the Annexe 1.

The vector data model is used to symbolize discrete features, using a set of geometric primitives: points (e.g. points of interest), lines (e.g. roads, rivers or railways) and polygons (e.g. municipalities or land uses).

The raster data model is most often used to represent continuously varying phenomena such as elevation or temperatures. It divides space into a regular array of rows and columns and is represented by cells or grid, which are usually squares, aligned in rows and columns.

The data file formats are: *shapefile* is a vector data file from ESRI, *ASCII* is a text file for storing raster data and *ECW* is an image format optimized for aerial and satellite imagery from Intergraph company.

- **Attributes and measurement scales**

Measurement scales dictate what kind of analysis can be performed with the attributes, and describe how values are assigned to features represented in GIS (Annexe 1). Nominal or categorical measurement scales include numerical values used to represent real-world objects or qualitative descriptions, for example, classes of land uses or vegetation types. Ordinal measurement scales involve values ordered according to a relative scale, as in the case of categories adopted to describe the conservation status of the habitats or the order of the autonomous roads. And interval measurement scales are used to denote quantities, but in this case the intervals between the values are based on equal or regular units, as in the case of the intervals employed for representing the variables of temperature, height and population.

3.6 GENERATING NEW GEOINFORMATION

Accessing spatial data is the first step of geoinformation processing, and this process involves subsetting, that refers to the process of extracting datasets based on data request; processing, that refers to any intentional manipulation of datasets for specific applications; and visualization, that is the graphical representation of requested results, masking the complexity of spatial data, which involves the conversion of the data into visual representation (Yang, R., 2011).

The data management and integration involves the collection and acquisition data from multiples sources al different scales, allowing access to heterogeneous spatial datasets in customized formats and contents, for its processing and subsequent visualization.

The process of GIS database implementation and management begins with needs assessment, continues through data acquisition and processing, and ends with the data analysis and interpretation. That, along with the data visualization by the creation of the maps, will constitute the fundamental part to elaborate the content of the Atlas.

The following items are taken into account for the implementation of the GIS database:

• An inventory of existing data sources is compiled, in accordance with the priorities of implementation according to the purposes and objectives.

• Geospatial data are designed and organized by establishing structure within and among datasets that facilitate their storage, retrieval and manipulation.

• Development of procedures followed both for data acquisition through the electronic media and for data archival storage and maintenance.

The development of the GIS database includes identifying the geographic data that are necessary to determine the environmental characteristics, setting limits of the study area and choosing the attributes for each feature.

GIS provides the tools to integrate large amounts of datasets, from a range of heterogeneous existing data sources, within a common reference framework that is defined by the geographic coordinate system. This allows for the combination of different data types, creating new information or executing complex queries that involve several data layers.

Management of the GIS database involves putting geospatial data into the same real-world coordinate system and joining the different coverage. Data from various sources are brought together into the common database, and re-projected from one mapping coordinate system into another for its integration using GIS software. Spatial data and associated attributes in the same coordinate system are viewed together and layered on top of each other to create maps.

The changes performed in the content of geographic data are: the modification, that includes the elimination of unneeded data and the addition of information content to raw data through analysis (e.g. reflect new subdivisions); extraction of data (e.g. create a new dataset as a subset of a larger dataset); and analysis of data (e.g. synthesize or abstract data to make it compatible with other datasets or integrate multiple datasets into a single dataset).

Using spatial analysis tools, the slope layer, the hillshading layer (azimuth 315 and elevation 45), and the flow direction to obtain the river basins layer are generated from DTM 5 m. Likewise, the reclassification is utilized to change the values of raster layers, for instance, in the case of distribution of heights, precipitation and temperature, which are subsequently converted to vector format.

The rainfall and temperature distribution layers are calculated from the location of different weather stations (figure 7), using the technique of Inverse Distance Weighted (IDW), which is a method of interpolation that estimates cell values by averaging the values of sample data points in the neighbourhood of each processing cell, creating a continuous surface representation.

These are some geoprocessing tools are manipulated: extract (clip, in the case of vector data, or extraction by mask, in case of raster data), e.g. to extract data of the study area; overlay (erase), e.g. to obtain the urban areas and the main roads outside the area of National Park; merge, e.g. to join data presented in different sheets (figure 8); and dissolve, e.g. to the generalization of the data from different sheets by removing the grids.

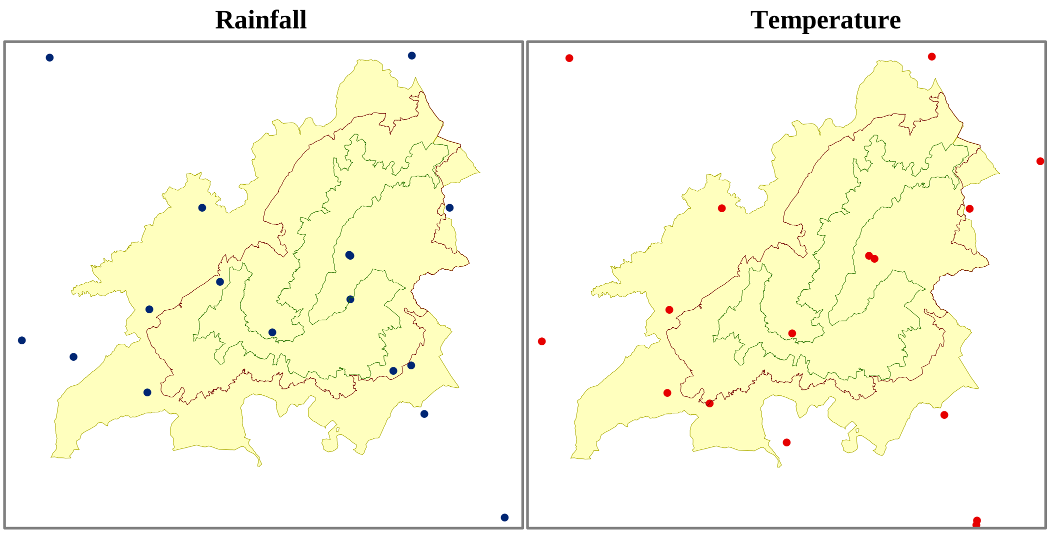


Figure 7. Situation maps of weather stations from which are obtained rainfall and temperature data.

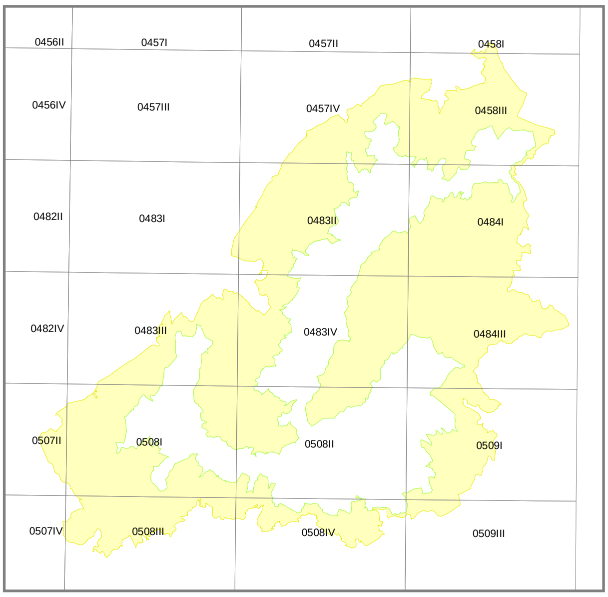


Figure 8. Grid Cells of National Cartographic Base (BCN25) at 1:25000 scale..

In addition, other GIS capabilities are employed for the creation of the maps: spatial database query, by selecting features that match a set of criteria to obtain information about them; and database operations to extract summary statistics or cross tabulations from the geographic attribute table of a data set, allowing for instance, computing the total area of each land use category or calculating the minimum and maximum height of them.

3.7 CORE DATASETS

The core datasets are defined as the set of spatial information necessary for the support of natural environmental analysis (table 4). The ten core datasets identified and described are: (1) administrative boundaries, (2) demography, (3) topography, (4) hydrography, (5) climate, (6) vegetation, (7) geology, (8) land uses, (9) protected areas, (10) urban areas and (11) transport network.

Table 3. Spatial layers, geometry of the spatial objects and their attributes.

Spatial Layers	Spatial Data Type **Geometry**	Tabular Table **Attributes**
Limit of the National Park	Polygon	Perimeter - Area
Limit of the Peripheral Protection Area	Polygon	Perimeter - Area
(1- 2) ADMINISTRATIVE BOUNDARIES AND DEMOGRAPHY		
Municipalities	Polygon	Area - Total population Population of Women - Population of Men Population under 16 years, 16 to 64, 65 and over Population Density
Centroids	Point	
Provinces	Polygon	Name
Autonomous Communities	Polygon	Name
Countries	Polygon	Name
Counties Livestock	Polygon	Name - Province - Autonomous Community
Counties Agricultural	Polygon	
(3) TOPOGRAPHY		
Geodesic Vertices	Multipoint	Height - Name
Peaks	Multipoint	Height - Name
Mountain Ranges	Polyline	Name
Contour Lines 100 m	Polyline	Category - Elevation
Digital Terrain Model	Cell	
(4) HIDROGRAPHY		
Dams	Polyline	Name
Rivers	Polyline	Name - Length - Category: permanent and non-permanent
Lagoons	Polygon	Name - Area
Reservoirs	Polygon	Name - Area

(5) CLIMATE

Weather Stations - temperature	Point	Name - average annual temperature
Weather stations - rainfall	Point	Name - average annual rainfall

(6) VEGETATION

Phytoclimatic Region	Polygon	Type
Potential Vegetation - Altitudinal Zonation	Polygon	Type - Description
Vegetal Stratum	Polygon	Type - Area - Percentage
Vegetation Type	Polygon	Type - Area - Percentage
Dominant Species or Formations	Polygon	Description - Area - Percentage
Agricultural Crops and Uses	Polygon	Type - Area - Percentage
Dominant Forest Species	Polygon	Description - Area - Percentage
Habitats	Polygon	CODE - Type
Conservation status of the habitats	Polygon	Category

(7) GEOLOGY

Geology	Polygon	Age - Description - Area - Percentage

(8) LAND USES

Land Cover (CLC) 1990	Polygon	Type - Area
Land Cover (CLC) 2006	Polygon	Type - Area - Percentage

(9) PROTECTED AREAS

Protected Areas: parks	Polygon	Figure - Name - Area
Special Protection Areas (SPAs)	Polygon	Name - Area
Site of Community Importance (SCI)	Polygon	Name - Area
Wetlands	Polygon	Name - Area
Biosphere Reserve	Polygon	Name - Area

(10) BUILDING AND URBAN AREAS

Place of Interest	Multipoint	Type: Monument, Religious Building - Name
Accommodation	Multipoint	Type: ski resort, camping area, mountain refuge - Name
Mining	Multipoint	
Urban roads	Polyline	Type - Name
Villages	Point	Name
Blocks	Polygon	

(11) TRANSPORT NETWORK

Dual Carriageway	Polyline	Name
Motorway	Polyline	Name
National Highways	Polyline	Name
Regional Roads	Polyline	Category: 1st order, 2nd order, 3rd order - Name
Tracks	Polyline	
Railway Stations	Multipoint	Name
Railway Line	Polyline	Name
Line High Speed Rail	Polyline	Name

OTHERS

Orthophoto	Cell	
Distribution of sheets National Map	Polygon	Number

4. CARTOGRAPHIC DESIGN: BASIS FOR THE MAPPING PREPARATION

After the GIS database is completed and the data are analysed, the next step is to create cartographic outputs. The geographic data, stored in layers inside the GIS database, are combined to make thematic maps which allowing the display of the spatial distribution of the attributes referred to specific geographic theme (Annexe 1).

The process of cartographic design and production is shown in the following graphic:

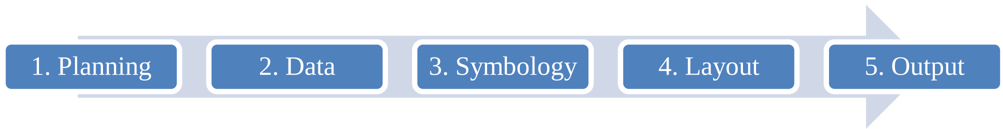


Figure 9. Process of Cartographic Design and Production.

The maps are a graphic representation of a portion of the territory on a two dimensional surface. They summarize large amounts of geographic information, communicating a message and getting the reader's attention.

The maps created here are made following the "Five Principles of Cartographic Design" proposed by British Cartographic Society's Design Group in 1999: Hierarchy with Harmony, Simplicity from Sacrifice, Maximum Information at Minimum Cost, Engage the Emotion to Engage the Understanding and Concept before Compilation. Every piece of work is checked to ensure that no errors appear in the final maps, hereby verifying way its quality.

4.1 TYPES OF MAPS AND SYMBOLOGY

The hillshade map is the base map for the cartography of the Atlas, which simulates the shadows that would be cast on the landscape.

Thematic maps can be divided in two groups:

- **Qualitative** maps show the location or distribution of nominal data (e.g the vegetation map, the geology map or the land uses map).

- **Quantitative** maps show the variations or changing magnitudes of spatial phenomenon in different places (e.g. the total population map or the height distribution map).

The total population and population density maps are choropleth maps, which use colours or patterns to represent the attributes associated with each municipality. This technique is employed for the representation of discrete nature data perfectly delimited. Darker colours represent higher data values and vice versa.

The isopleth maps generalize and simplify data with a continuous distribution: the rainfall map is an isohyets map which shows lines indicating places of equal rainfall; the temperature map is an isotherms map which shows lines that are formed by points of equal temperature; and the elevation map is a contour lines map that connect points of equal height on the earth's surface.

Quantitative symbology is employed for the classification of the attributes values, such as slope, temperature, rainfall, population and population density, into interval categories using manual techniques.

4.2 MAP ELEMENTS AND COMPOSITION

The maps are designed and built taking into account the harmonious integrating its elements, colours and typography. The unambiguity of the symbols and the highlighting of the most relevant information facilitate readability and its understanding.

The data frame, in the most cases, has the following characteristics: 18 cm width and 17,6 cm height. The space is subdivided reasonably and the various map elements (scale bar, north arrow and legend) are positioned and aligned considering the proportion between them, to generate a good visual balance according to the design criteria.

ESRI NORTH is the type of **North Arrow** preferred to be displayed in the map, with *60 pts*. size, *Times New Roman* font, *Gray 70%* colour and *x=4cm/y=16cm* position.

The scale preferred to the representation of the most maps, expressed as ratio, is 1:250000, what means that each centimetre on the map represents 2,5 kilometres in the real world. The **scale bar** has the advantage of remaining accurate regardless of map enlargement or reduction.

Number of divisions: *4 / Number of subdivisions: 0*
Units: *Km - label Position: after bar – Gap: 2,8pt*
Number: above the bar – Gap: 2pt
Text: *Times New Romans 8 – Color: Gray 70%*
Bar: *Color: Gray 50% Size .– 5pt*
Size: *Width: 4,1cm – Height: 0,6cm*
Position: *x:15,64cm – y:0,92 cm*

The **legend** is the key identifier, whose features are represented on a map to help the user understand the information at hand with direct use of symbols as explanations.

The data are classified and represented using **graphic symbols** that enables the map reader to interpret the real-world objects, which are referred by points (e.g. points of interest), lines (e.g. roads, railways, rivers and contour lines), areas (urban areas and vegetation type) and surfaces (e.g. temperature distribution). The way in which they are represented was explored in 1967 by Bertin, who established the following visual variables used to provide a palette from which to represent perceived differences on a map: size, value, colour, orientation, shape, texture and position.

To fully understand the cartographic symbolization, one must realize the relationship among the fundamental types of geographic data, the measurement levels, the forms of cartographic symbolization, and the visual variables, or the graphic elements that make up a specific symbol (McMaster, R.B, 2001).

Lettering appears in the legend and labelling of the map (table 4). Characteristics such as font, size, style or colour are employed systematically to underscore kind and hierarchy of map objects.

With respect to the digital output, the maps are exported to a graphic file format PNG with 300 dpi of resolution for its distribution on the web site. Most computer systems admit 256 grades of colour in each of the red, green, and blue (RGB) additive colours, generating over 16 million possible colours.

	Font	Size (pts.)	Style	Alignment	Color
Legend					
Title ‘Legend’	TNR	12	bold	Center	Black
Other titles	TNR	10	bold	Left	Black
Text	TNR	10	normal	Left	Black
Numbers	TNR	10	normal	Left	Black
Labelling					
Provinces	TNR	8	Underline	Center	Black
Autonomous Communities	TNR	8	Normal	Center	Black
Countries	TNR	8	Normal	Center	Black
National Parks	TNR	12	Normal	Center	Black
	Font	**Size** (pts.)	**Style**	**Alignment**	**Color**
Grid Cells	Arial	10	Normal	Center	Black
Geodetic Vertices	Arial	9	Itlalic	Center	Cherrywood Brown
Mountain Ranges	TNR	12	Italic	Center	Dark Umber
Colour Lines	Arial	8	Italic	Center	Dark Umber
Rivers	Arial	8	Italic	Center	Ultra Blue
Lagoons	Arial	8	Italic	Center	Dark Navy
Reservoirs	Arial	8	Italic	Center	Dark Navy
Protected Areas	TNR	8	Normal	Center	Black
Special Protection Areas (SPA)	TNR	8	Normal	Center	Black
Sites of Community Importance (SCI)	TNR	8	Normal	Center	Black
Municipalities	TNR	9	Normal	Center	Black
- TNR: Times New Roman					

Table 4. Lettering for annotations on the maps.

5. VISUALIZING THE GEOGRAPHIC INFORMATION: DESIGN AND MAKING OF THE ATLAS OVER THE INTERNET

The digital Atlas of National Park '*Las Cumbres de la Sierra de Guadarrama'* is the final outcome of a series of data processing steps, beginning with collection, through editing, management and analysis, and concluding with the creation of the maps. Each one of these activities transforms the available geographic information in the GIS database until the maps are in the appropriate form to display them on the screen computer. The digital maps, along with text and photographs, are the contents of the website that will be displayed by the readers. The figure 10 shows the digital production process of the Atlas.

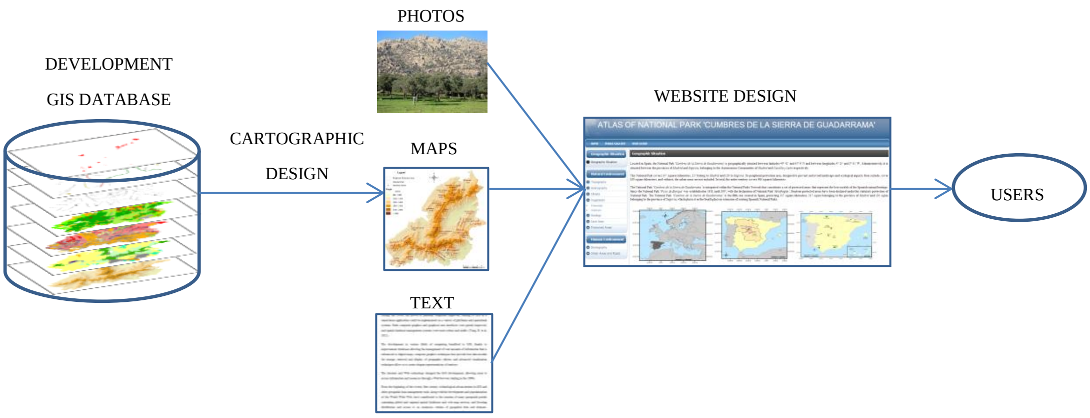


Figure 10. The Digital Production Process of the Atlas.

The display of spatial information analysed is shown in the form of maps, which are published on the Internet by means of the design of an Atlas embedded in a website that is created in HTML (HyperText Markup Language) format, allowing the elaboration of multimedia documents with formatted text, images and tables.

The visualization of the Atlas through the World Wide Web (WWW) helps to facilitate the knowledge of this territory, showing each one of the elements that characterize the environmental and the natural values of the National Park and its surroundings.

The host name for the website of the digital Atlas of National Park '*Las Cumbres de la Sierra de Guadarrama*' is http://www.geomundo.es. The digital Atlas is presented as a collection of maps accompanied by photographs and text, in a visually appealing and user-friendly interactive website.

5.1 SOFTWARE

The design and making of the website is performed with the open source software Joomla 1.5.5, which is a Content Management System (CMS). To the editing and retouching photographs, the software Adobe Photoshop CS5 is used.

The operation of the Internet is run by two major players, a server where data is stored and a customer who requests or uses that data. This interaction is known as client-server.

5.2 STRUCTURE OF THE ATLAS

The thematic content of Atlas is divided into three sections that describe the situation and the physical and human environment in the territory of the National Park '*Las Cumbres de la Sierra de Guadarrama'* and it surroundings: geographic situation, physical environment and human environment. These are broken down into different themes: topography, hydrography, climate, vegetation, geology, land uses, protected areas, demography, and urban areas and roads.

5.3 LAYOUTS AND ELEMENTS

After an initial planning stage in which structure and content are specified, all atlas elements (maps, text and photographs) are combined to their inclusion onto the website.

The user interface design of the website includes (figure 11):

- At the top, the header containing the title: Atlas of National Park *'Las Cumbres de la Sierra de Guadarrama*';
- At the bottom, the footer containing general information on the website;

- On the right, the main menu from which the various sections and themes of the Atlas are accessed;
- A top menu, from which the home page, the map gallery only for the National Park area and the photograph gallery can be accessed.
- And finally, the content that include the maps and the accompanying text.

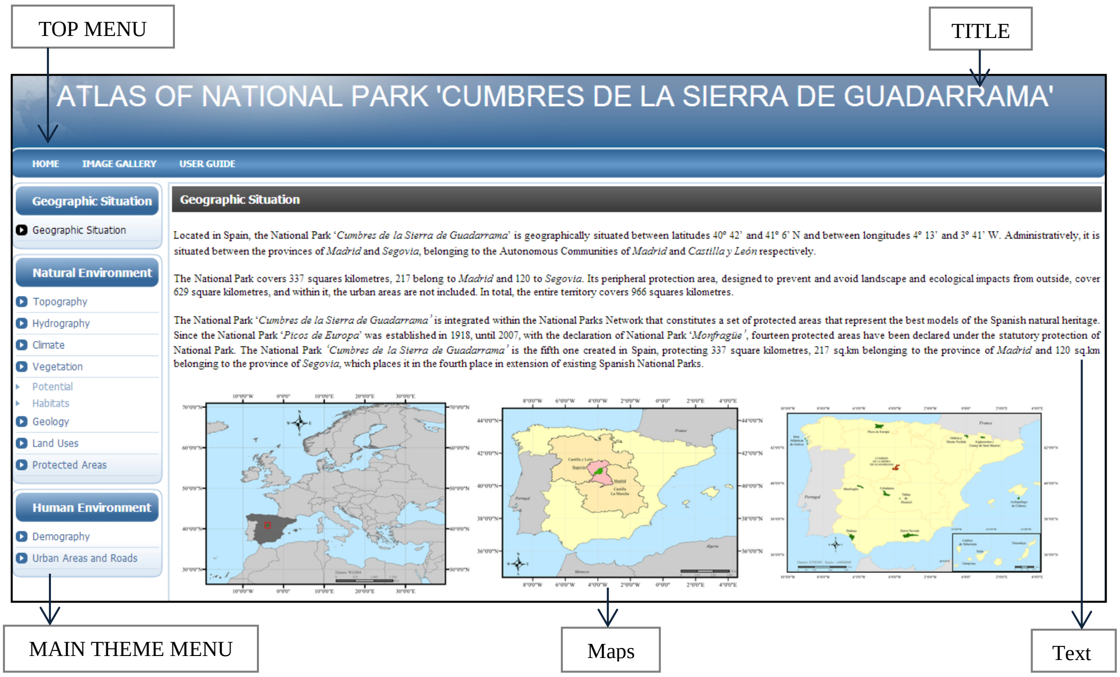


Figure 11. User Interface of the Website.

To open the map gallery, it is required click on them. This will open a viewer that lets display and explore the maps, and even enlarge (figure 12). Similarly, photo gallery can display the photographs by selecting the thumbnails (figure 13).

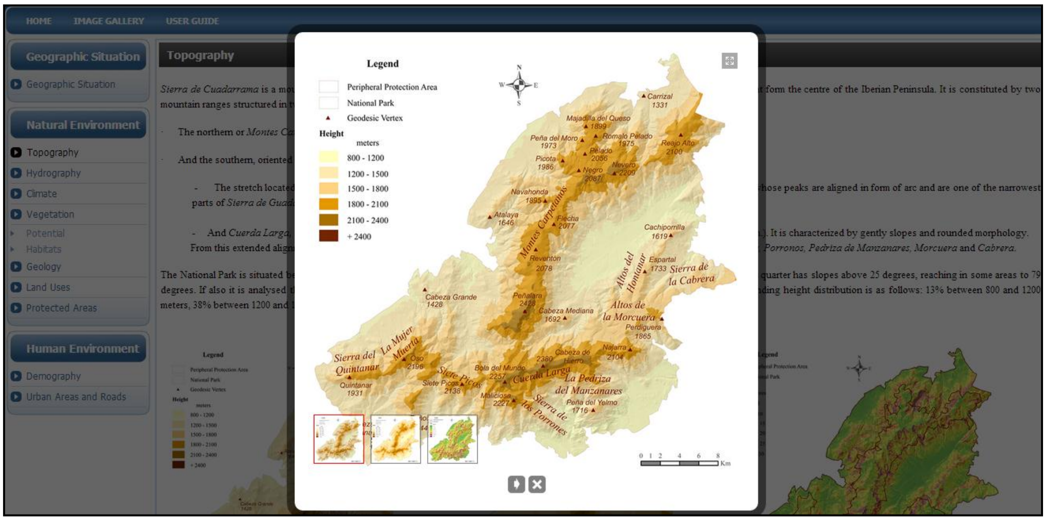


Figure 12. Map Gallery.

Figure 13. Photo Gallery.

The home page presents a slideshow, which let the transition of images with introductory text and the selection of the different themes of the Atlas by mean of links (figure 14).

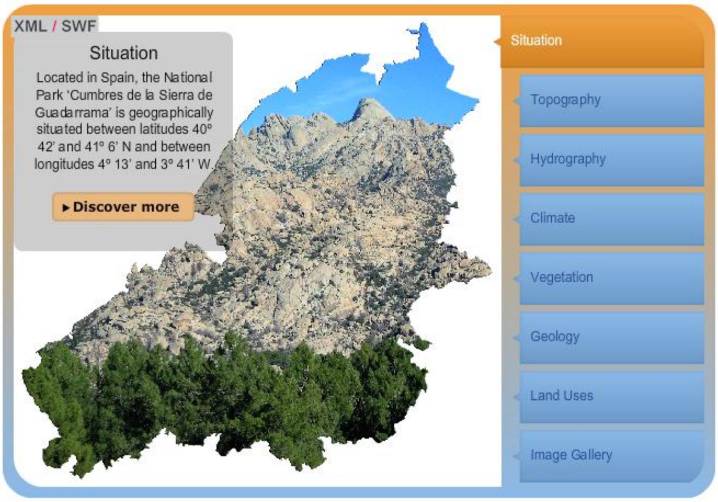


Figure 14. Slideshow on the Home Page.

6. THE ATLAS OF THE NATIONAL PARK '*LAS CUMBRES DE LA SIERRA DE GUADARRAMA*'

6.1 PHYSICAL ENVIRONMENT

6.1.1 Topography and Refief

Sierra de Cuadarrama is a mountain system that is part of the Central System, natural division between north and south of the plateaus that form the centre of the Iberian Peninsula. It is constituted by two mountain ranges structured in two main axes:

- The northern or *Montes Carpetanos*, oriented in direction SW-NE, in which highlights the peaks *Peñalara* (2428 m.) and *Nevero* (2209 m.);

- And the southern, oriented in direction W-E, and divided into two sections:
    - The stretch located at west of *Bola del Mundo*, comprising *Mujer Muerta*, whose highest peak is *Oso* (2196 m.), and *Siete picos*, whose peaks are aligned in form of arc and are one of the narrowest parts of *Sierra de Guadarrama.*

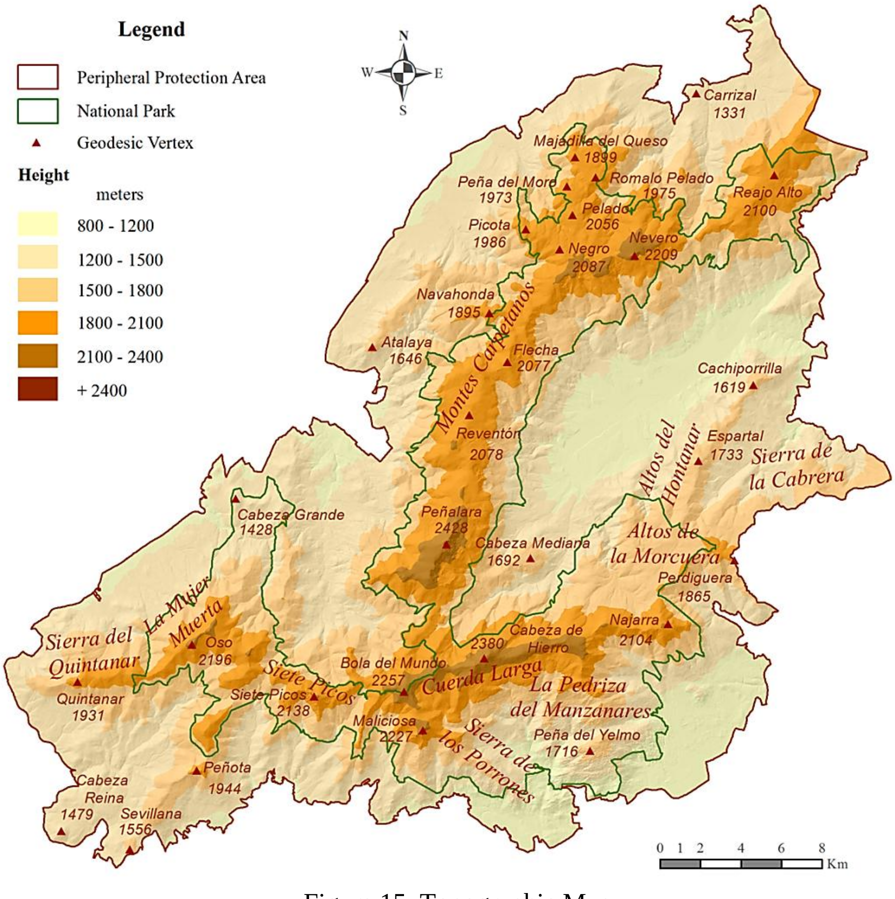


Figure 15. Topographic Map.

- And *Cuerda Larga*, situated between *Bola del Mundo* (2257 m.) and *Najarra* (2104 m.), where highlights *Cabeza de Hierro* (2380 m.). It is characterized by gentle slopes and rounded morphology.

  From this extended alignment emerge others mountain ranges, which present a lower elevation and different orientations, as *Maliciosa*, *Porrones*, *Pedriza de Manzanares*, *Morcuera* and *Cabrera*.

The National Park is situated between 946 and 2427 meters. Practically, 85 per cent of this territory is located above 1500 meters, and nearly a quarter has slopes above 25 degrees, reaching in some areas to 79 degrees (figure 17). If the peripheral protection area is also analyzed, the whole territory is elevated to between 823 and 2427 meters, and the corresponding height distribution is as follows: 13% between 800 and 1200 meters, 38% between 1200 and 1500 meters, 30% between 1500 and 1800 meters, and 19% above 1800 meters (tables 7 and 8).

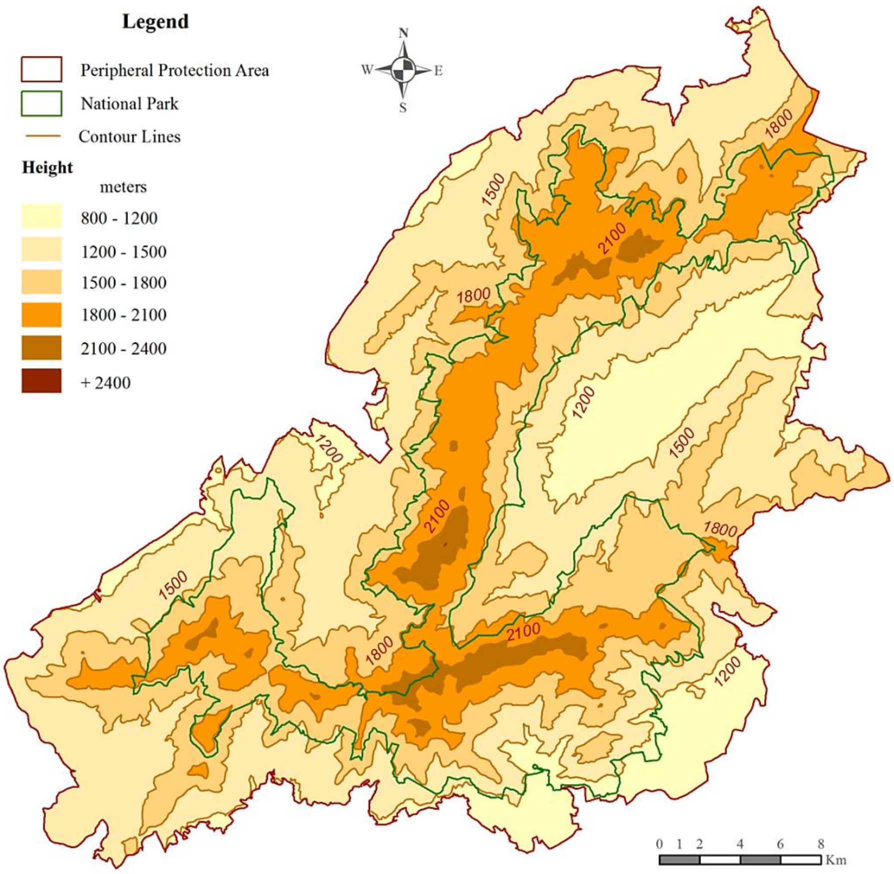


Figure 16. Distribution map of heights.

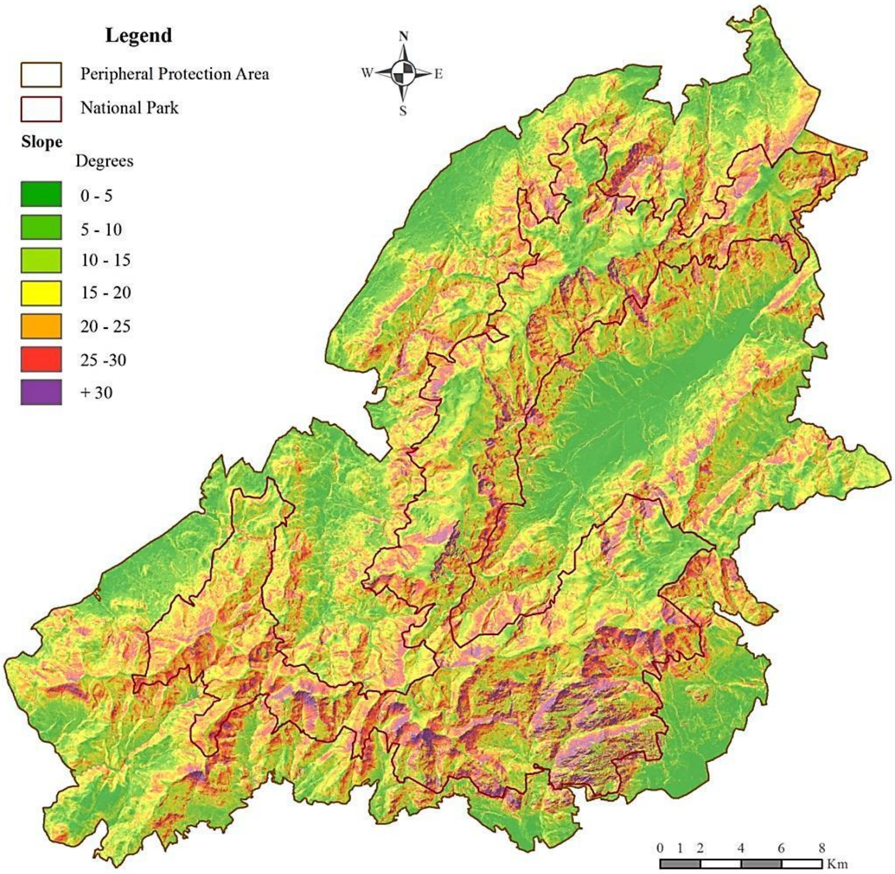


Figure 17. Slopes Map.

6.1.2 Hydrography

Sierra de Guadarrama is the dividing line between two of the major river basins of the Iberian Peninsula: *Duero*, at the north, and *Tajo*, at south. The watershed coincides with the boundary of separation between the provinces of *Madrid* and *Segovia*. Many rivers and streams flow through this territory, where numerous natural springs are born.

Among the rivers of the northern slope, stands the *Eresma* River, which rises in *Valsaín* Valley at the confluence of the streams flowing down from the slopes of *Peñalara*, *Siete Picos* and *Montón de Trigo*. This river, alongside *Moros* River, is tributary of *Adaja*, and *Pirón* is tributary of *Cega* River. Both, *Cega* and *Adaja* are tributaries to the left of *Duero*.

Among the rivers of the southern slope, stands the *Lozoya* River, which in its upper course receives water from the streams coming from the massifs of *Peñalara* and *Cuerda Larga*, originating from the wide *Lozoya* Valley, between the mountain ranges *Cuerda Larga* and *Montes Carpetanos*, and whose flow is regulated by the reservoir of *Pinilla*. This river, alongside the *Manzanares* River, which rises on the southern slope of *Cuerda Larga* and is the main axe of the Regional Park *Cuenca Alta del Manzanares*, and the *Guadalix* River, which rises in *Sierra de la Morcuera*, are tributaries of *Jarama* River, tributary to the right of the *Tajo*.

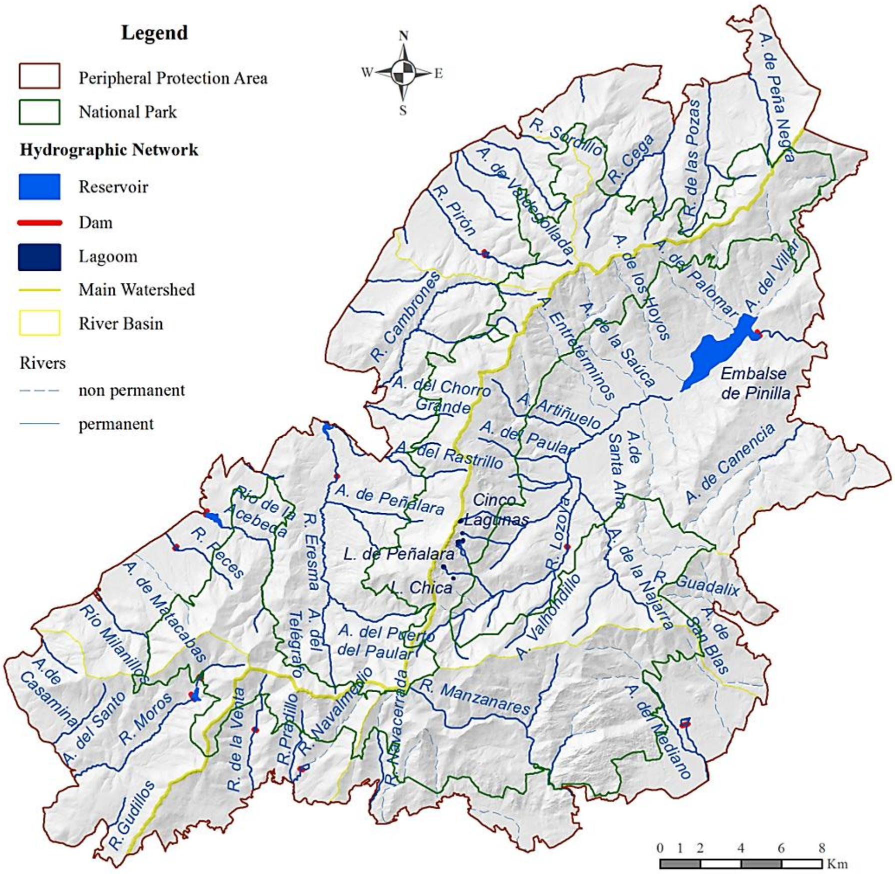


Figure 18. Map of the Hydrographic Network.

Near the *Peñalara* peak, 2,000 meters high, there are a set of small glacial lagoons that are protected. *Grande* lagoon, *Chica* lagoon and lagoon of Birds are some of them.

6.1.3 Climate

The climate is Continental Mediterranean, with cold winters and summers with low water mark, and varies greatly depending on the height. The annual rainfall is between 363 and 1292 mm, and the average annual temperature is between 8 and 13 °C[4].

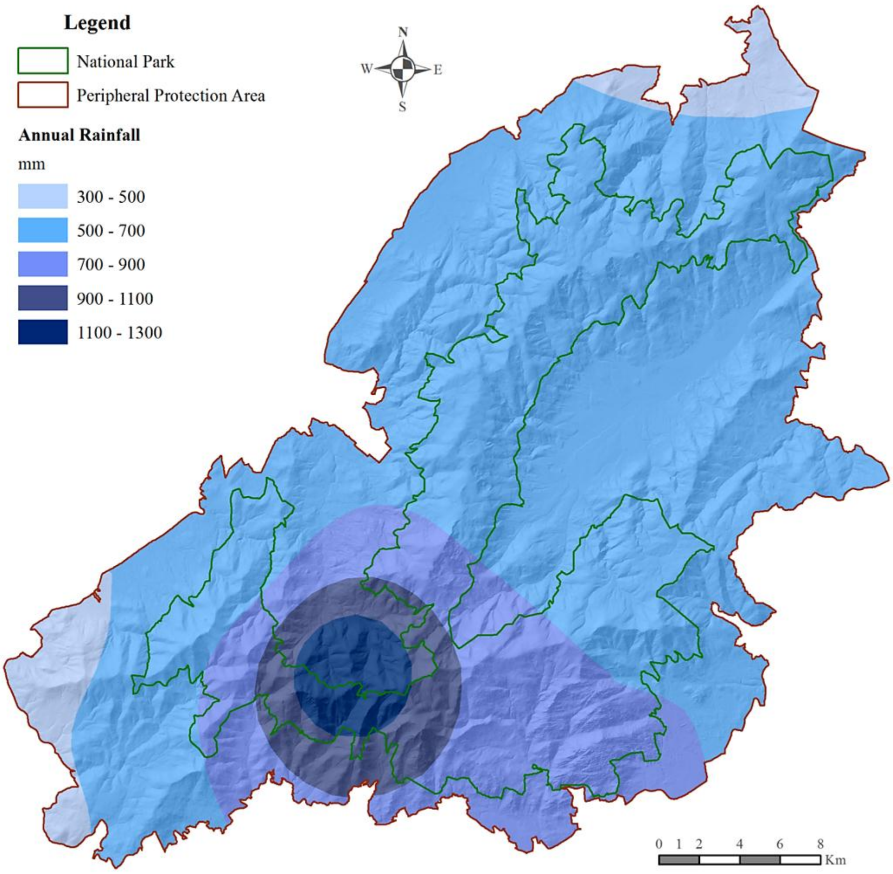


Figure 19. Distribution map of Annual Rainfall.

[4] Average annual data for the 2011 year obtained from State Meteorological Agency (AEMET).

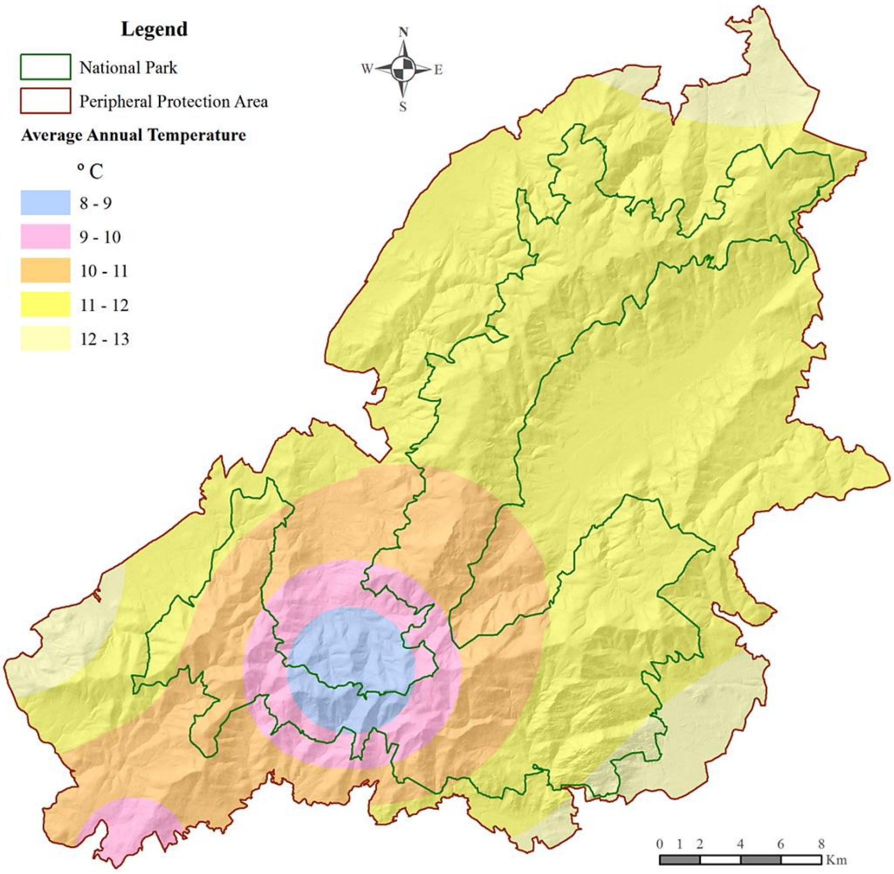


Figure 20. Distribution map of Average Annual Temperature.

6.1.4 Vegetation

This Mediterranean region has different potential vegetal communities distributed in altitudinal zones. The potential vegetation are those 'stable vegetal communities that would exist if man action ceases to influence and alter ecosystems' (Rivas-Martinez, 1978).

- Cryoromediterranean (1300-2250 m.): Grassland (*Festuca curvifolia*);
- Oromediterranean (2000-2450 m.): Pine forest, broom and junipers (*Juniperus communis subsp. nana*);
- Supramediterranean (900-2000 m.): *Quercus pyrenaica* forest, *Quercus faginea* forest and Holm Oaks (*Quercus ilex*);
- (900-1450 m.): Ash trees (*Fraxinus sp.*).

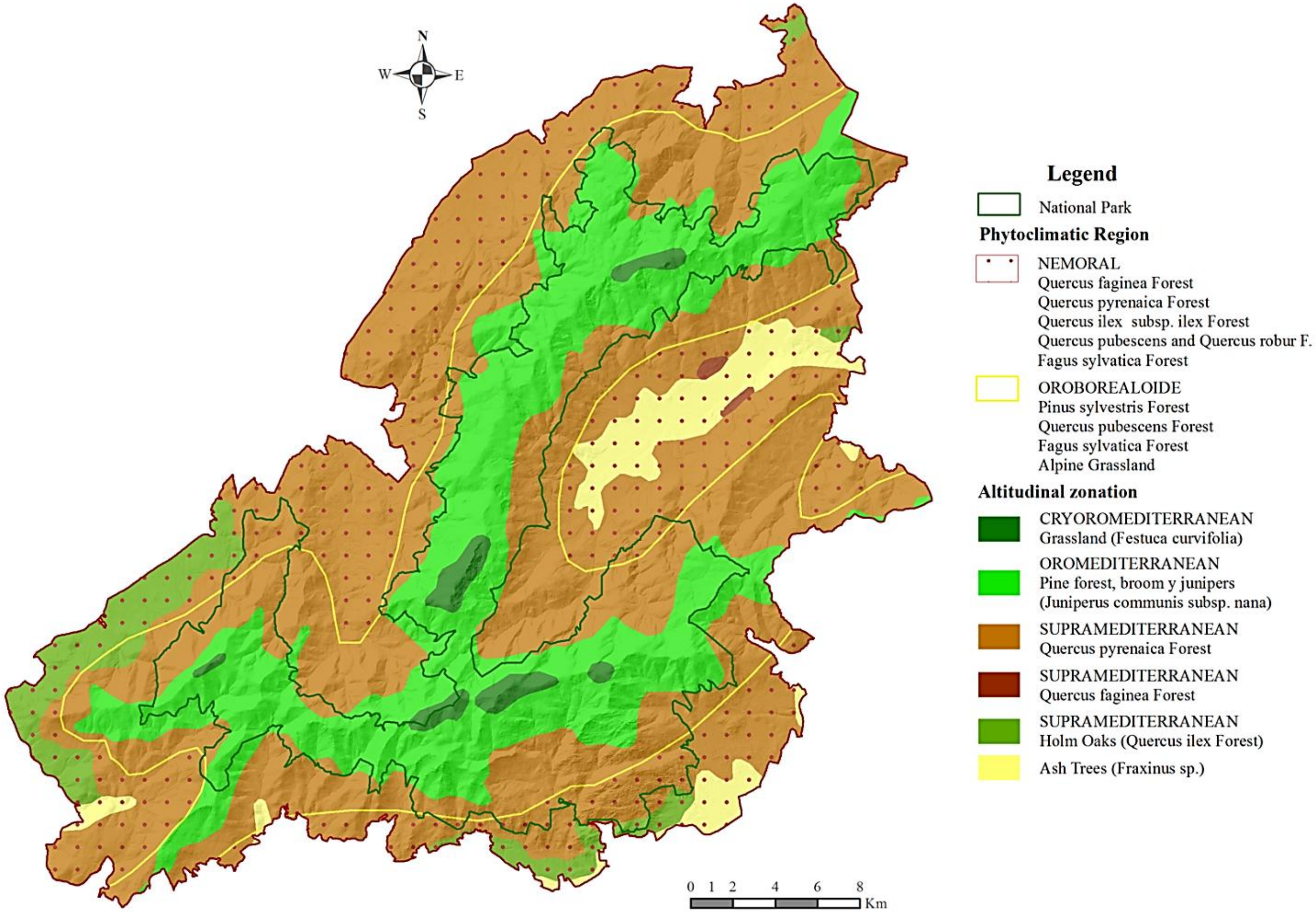


Figure 21. Map of Potential Vegetation and Altitudinal Zonation.

According to the climatic classification elaborated by Allúe-Andrade in 1990, this territory belongs to two zones, each one with certain vegetation:

- Nemoral: *Quercus faginea* forest, *Quercus pyrenaica* forest, *Quercus ilex subsp. ilex* forest, *Quercus pubescens* and *Quercus robur* forest and *Fagus sylvatica* forest.
- Oroborealoide: *Pinus sylvestris* forest, *Quercus pubescens* forest, *Fagus sylvatica* forest and Alpine grassland.

Regarding the types of real vegetation and dominant species or formations in the area, it should be noted (figures 22 and 23, table 9):

- Six per cent is vegetation that grows in rocky outcrops or compact lava (924-2427), and comprised of formations as 'rocky desert-*Quercus pyrenaica-Quercus ilex rotundifolia'* (33%) and 'rocky desert-*Cytisus laurifolius-Cytisus ladanifer'* (21%). The oaks, which resist drought and high summer temperatures and low winter temperatures, are often accompanied by rock rose.

- Thirteen per cent is High Mountain vegetation (1231-2410 m.), consisting of '*Cytisus purgans-Juniperus communis subsp. alpine'* (70%). Broom and junipers are located in the vicinity of the peaks.

- Almost a quarter of it is covered by Taiga (1054-2206), comprising of *Pinus sylvestris* (57%) and *'Pinus sylvestris-Cytisus purgans'* (12%), that grows on the wide slopes of the mountain range.

- More than half of the territory is covered by Sub-sclerophyllous forest (894-2145 m.), consisting of *Pinus sylvestris* and *Quercus pyrenaica* (46%). This last specie forms the deciduous oak forest, which has great ability to sprout.

- And, finally, four per cent of the territory is covered by Hydrophyllum vegetation, comprised of 'swath meadow-grassland-*Fraxinus angustifolia' (*29%). In these lower areas (900-1460 m.), where soils are deep and rich, ash forests appear. These areas have been exploited by man turning them into swath meadows for cattle feeding, creating pastures zones.

The distribution of the vegetation types within the National Park is: 33% Taiga, 30% High Mountain, 21% Sub-sclerophyllous and 14% rocky outcrops.

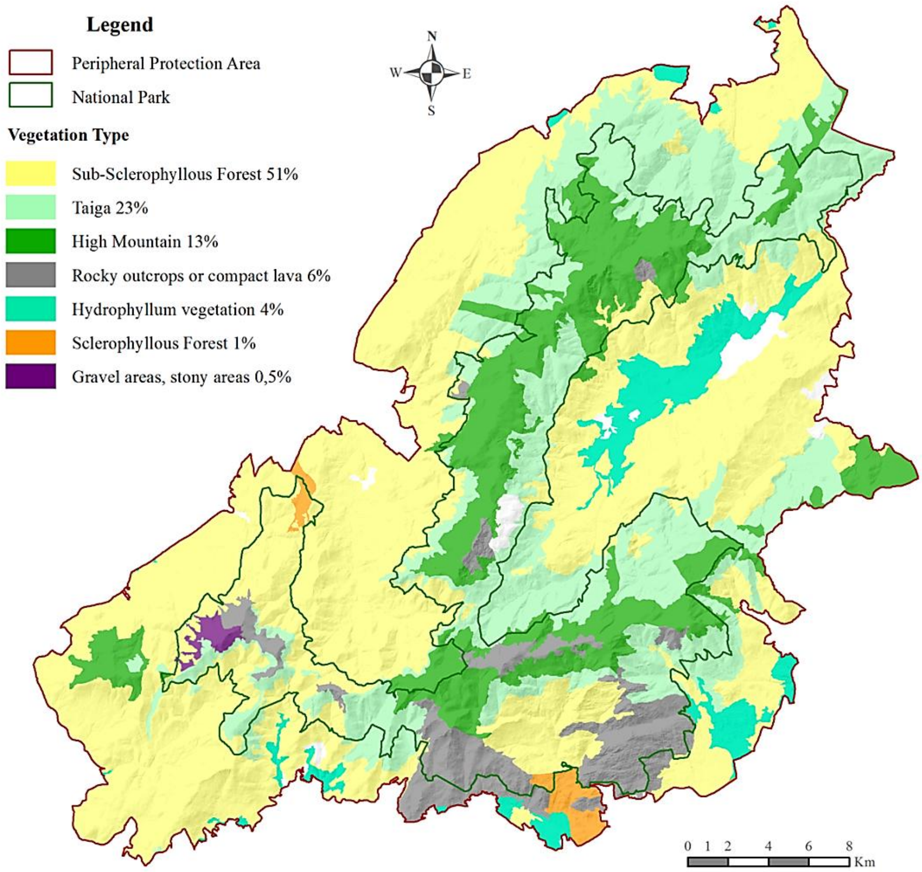


Figure 22. Map of Vegetation Types.

The dominant species or formations in the whole are *Pinus sylvestris* (28%), '*Cytisus purgans-Juniperus communis alpina'* (10%) and *Quercus pyrenaica* (8%) (figure 23). Within the National Park predominates *Pinus sylvestris* (37%), '*Cytisus purgans-Juniperus communis alpina'* (37%), '*Pinus sylvestris-Cytisus purgans'* (9%) and 'rocky desert-*Quercus pyrenaica-Quercus ilex rotundifolia'* (8%).

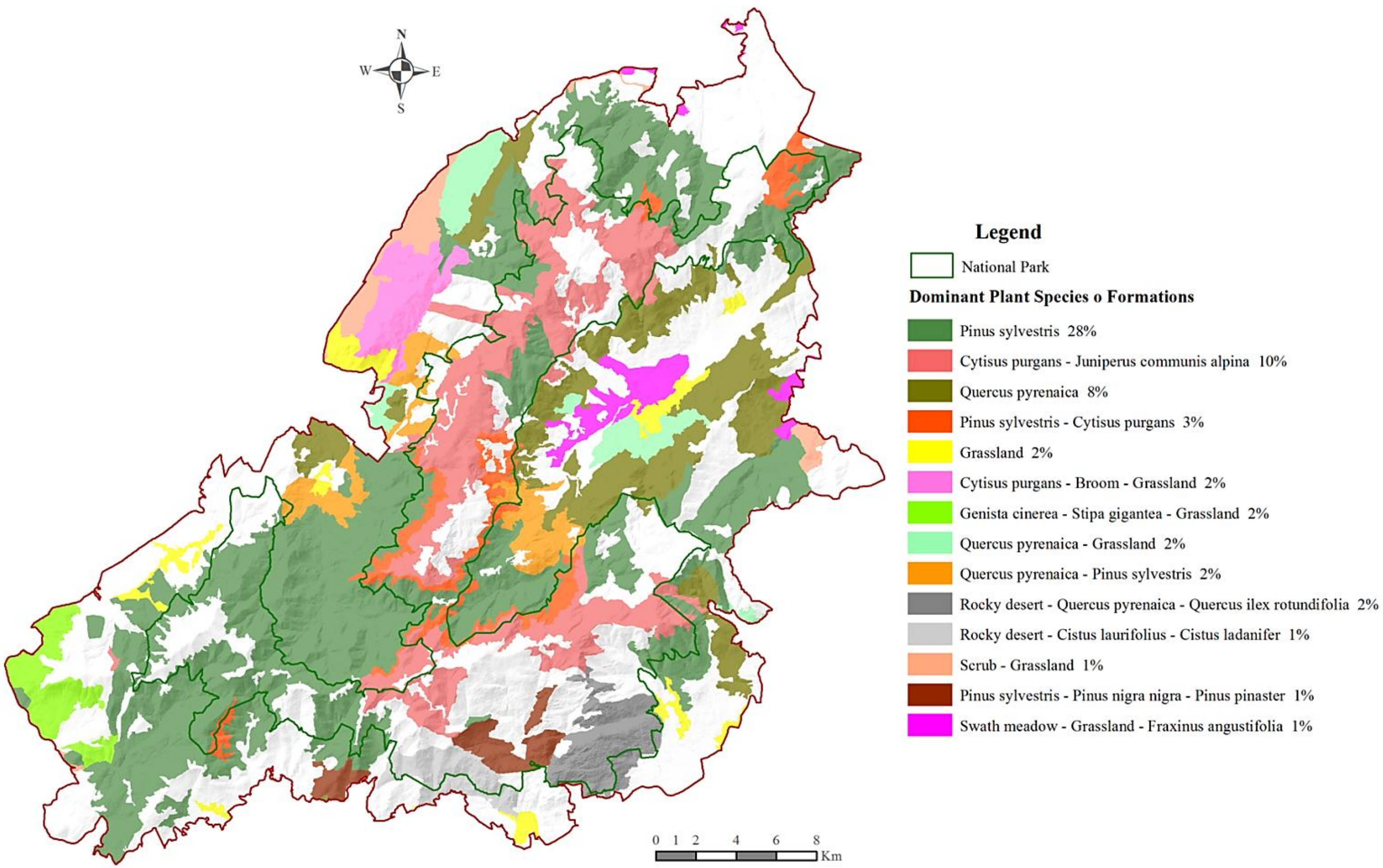


Figure 23. Map of Dominant Species or Formation.

If the vegetal stratum in over the entire area is analyzed, 47% is tree layer composed of forests, 46% is scrub layer and 7% is herbaceous layer composed of grassland. In the case of the National Park, 57% of the vegetation are forests, 39% scrubs, and the remaining 4% is composed of grassland and the rock-covered areas.

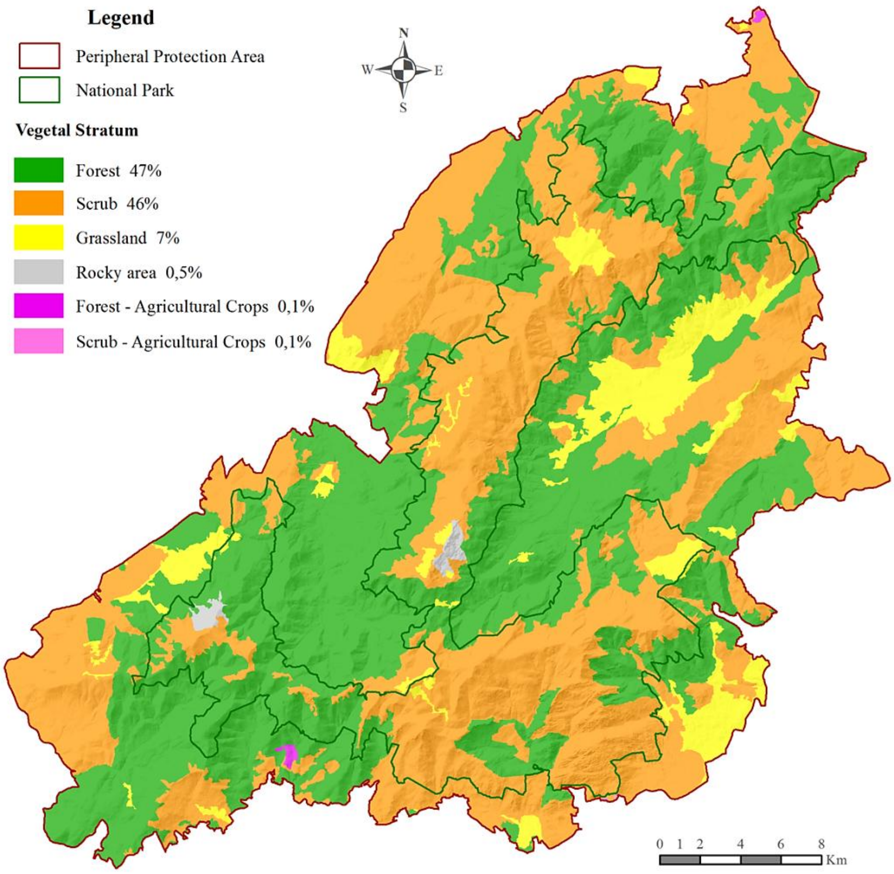


Figure 24. Map of Vegetal Stratum.

The agricultural crops and forest lands map shows that wooded forest covers 51% of the territory and 43% of it is treeless forest (figure 25). The dominant forest species or formations are *Pinus sylvestris* (72%), *Quercus pyrenaica* (14%) and ‘*Pinus sylvestris-Pinus pinaster’* (8%). These one are also the representative species in the area of the National Park (figures 26 and 27).

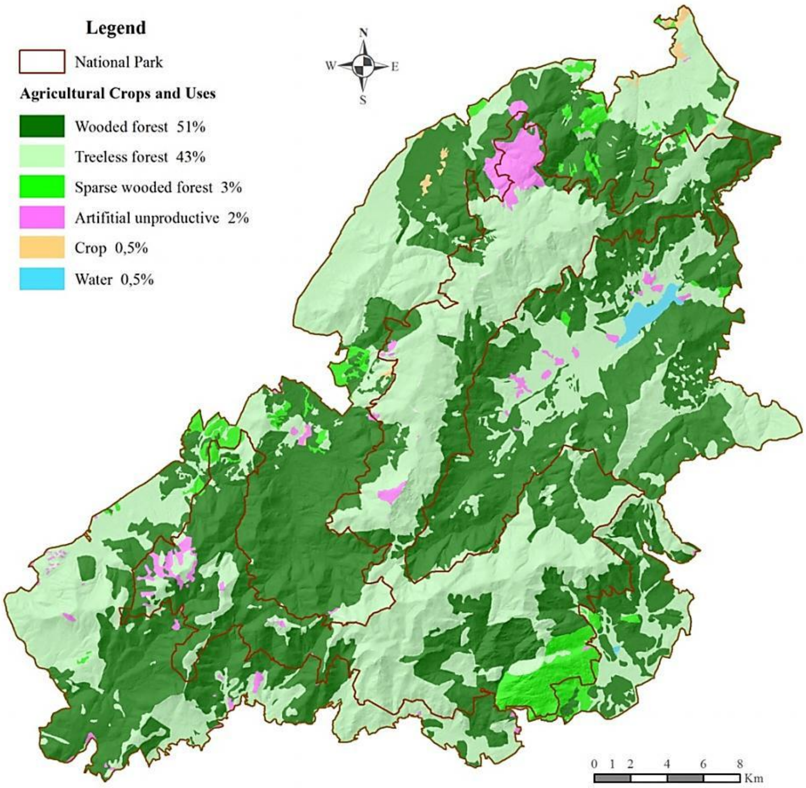


Figure 25. Map of Agricultural Crops and Forest Land.

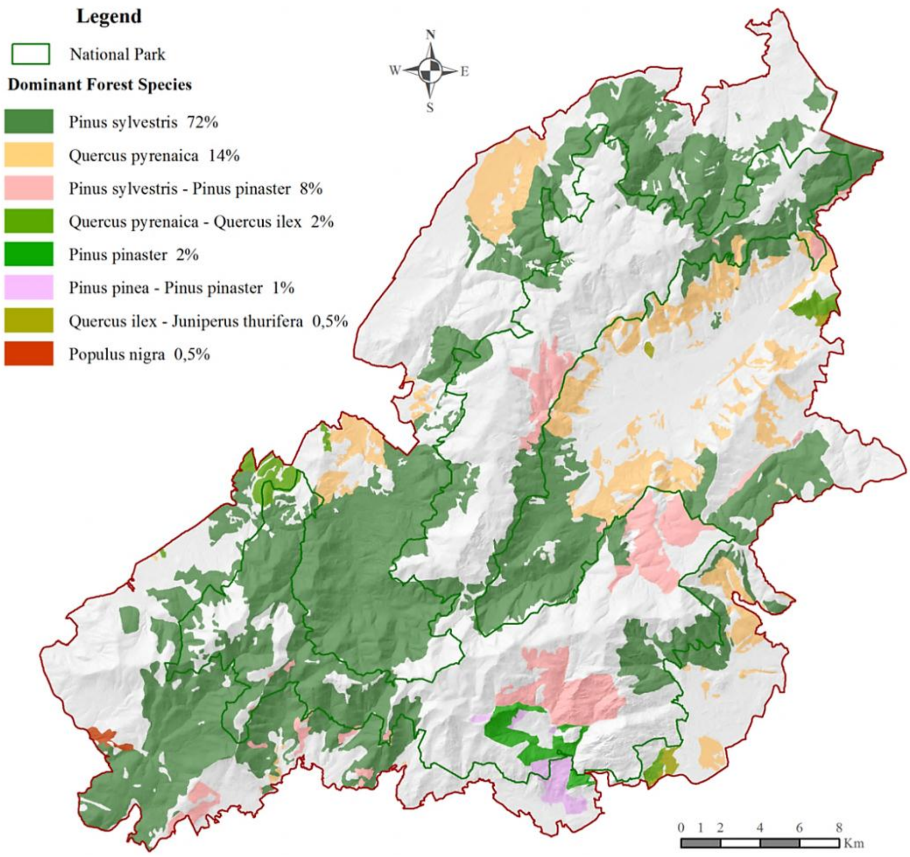
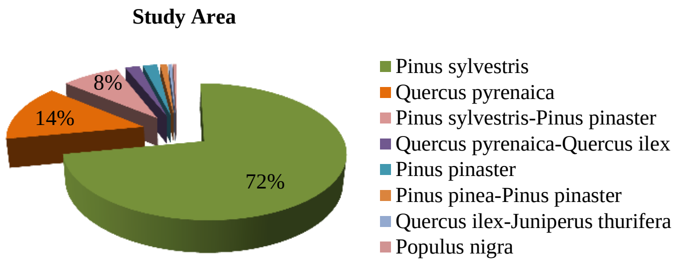


Figure 26. Map of Dominant Forest Species or Formations.



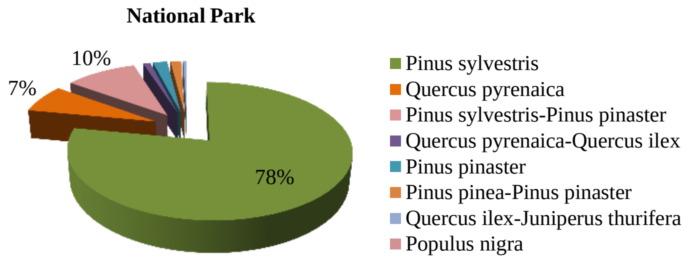


Figure 27. Dominant Forest Species and Formations in the area.

Twenty five habitats, according to the Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora, are included within the area, presenting most of them excellent condition (figures 28 and 29, table 10). It is stressed 'mountain *Cytisus purgans* formations' (51%) (1200-2400 m.), forming part of 'sub-mediterranean and temperate scrub'; 'endemic oro-Mediterranean heaths with gorse' (16%) (900-1900 m.), forming part of 'temperate heath and scrub'; and 'Galicio-Portuguese oak woods with *Quercus robur* and *Quercus pyrenaica'* (13%) (900-1700 m.), being part of 'Mediterranean deciduous forests'. 'Mediterranean temporary ponds', 'pseudo-steppe with grasses and annuals of the *Thero-Brachypodietea',* 'endemic forests with *Juniperus* spp.' and blanket bogs' are priority species or habitats (in danger of disappearing).

In the National Park, 'mountain *Cytisus purgans* formations' (75%) are highlighted, but 'siliceous rock with pioneer vegetation of the *Sedo-Scleranthion'* and 'Oro-Iberian *Festuca indigesta* grasslands' are also important habitats. 'Pseudo-steppe with grasses and annuals of the *Thero-Brachypodietea'* and 'blanket bogs' are the priority species or habitats.

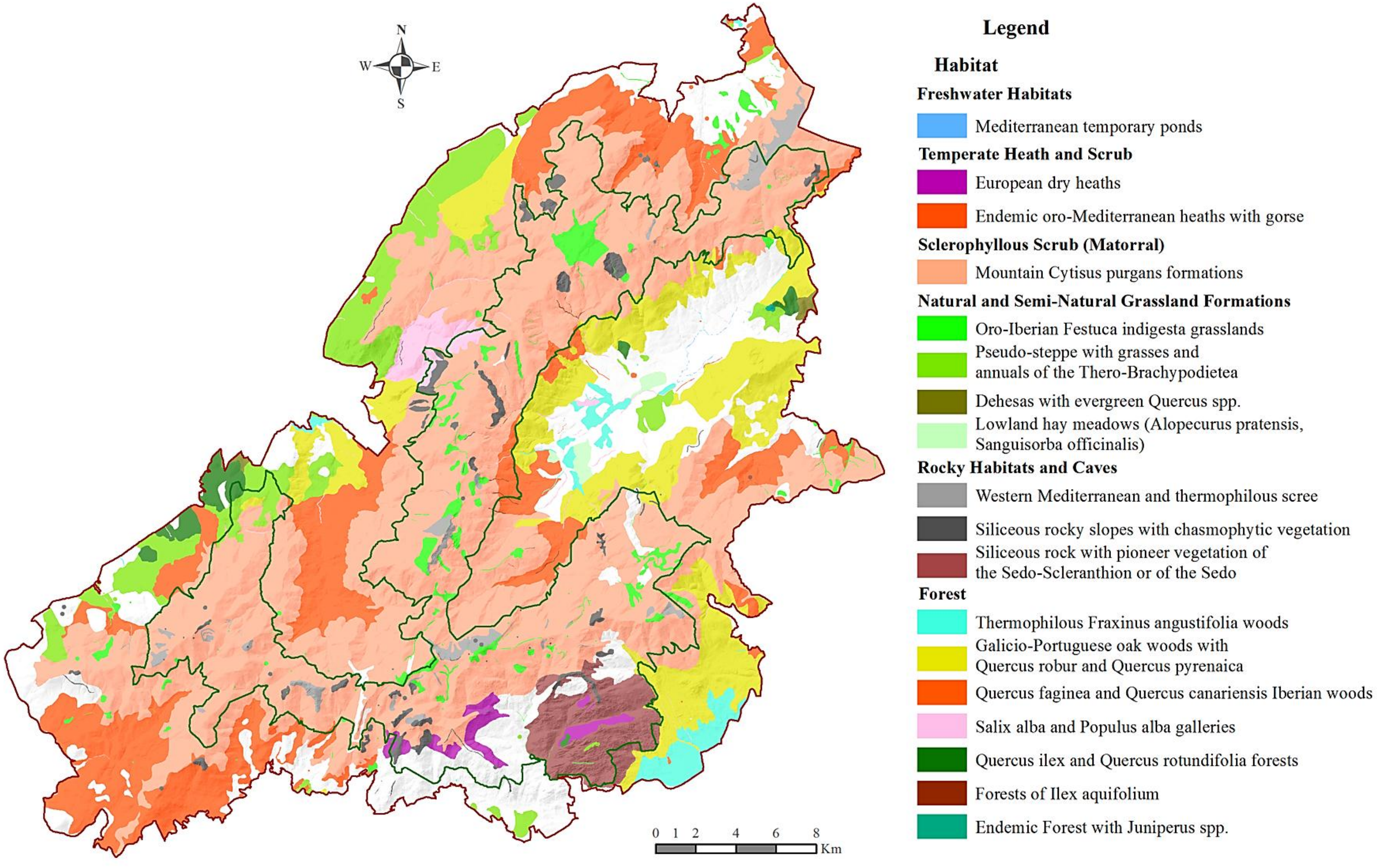


Figure 28. Map of Habitats.

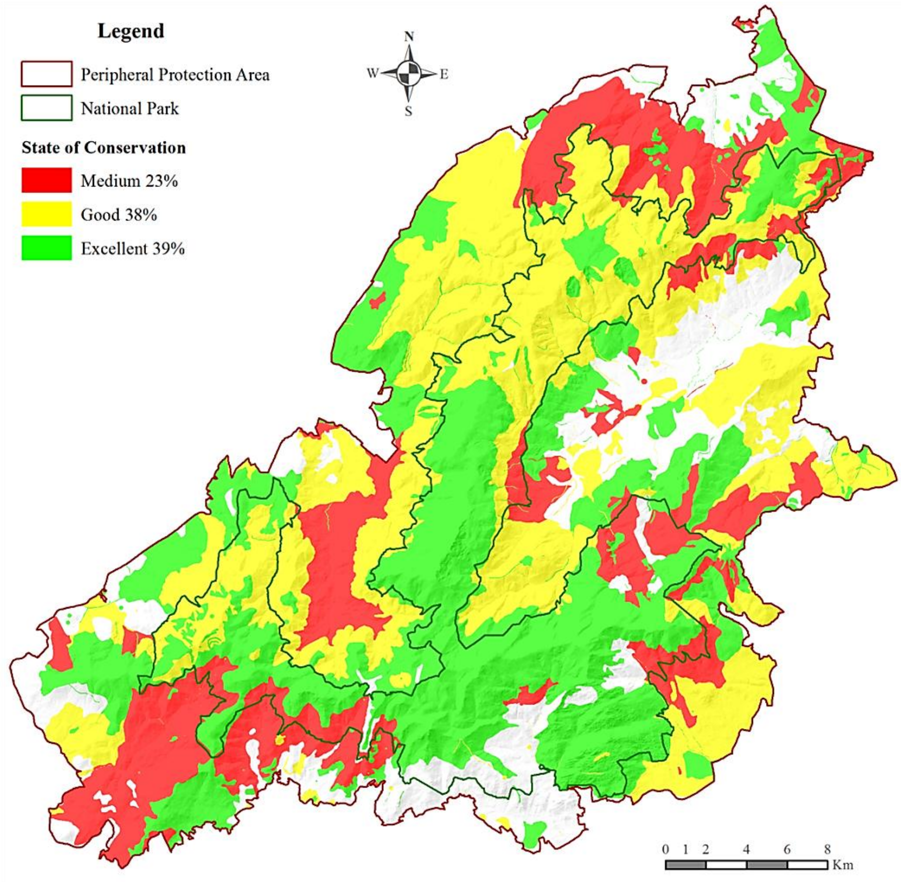


Figure 29. Map of the Conservation Status of the Habitats.

6.1.5 Geology

Sierra de Guadarrama is one of the oldest orographic systems of the Iberian Peninsula. The predominant geological materials are gneisses (metamorphic rocks) created during the Paleozoic Era, and granites (igneous rocks) generated between Carboniferous and Permian Periods (figure 30 and 31). The fragmentary rubbles, composed of boulders and pebbles, and originated between Upper Pleistocene and Holocene, are very characteristic of the area.

The geological structure, in the form of step, is originated by parallel faults called horst, causing the elevation of blocks that form the mountain ranges and sinking others that form valleys, like *Lozoya*.

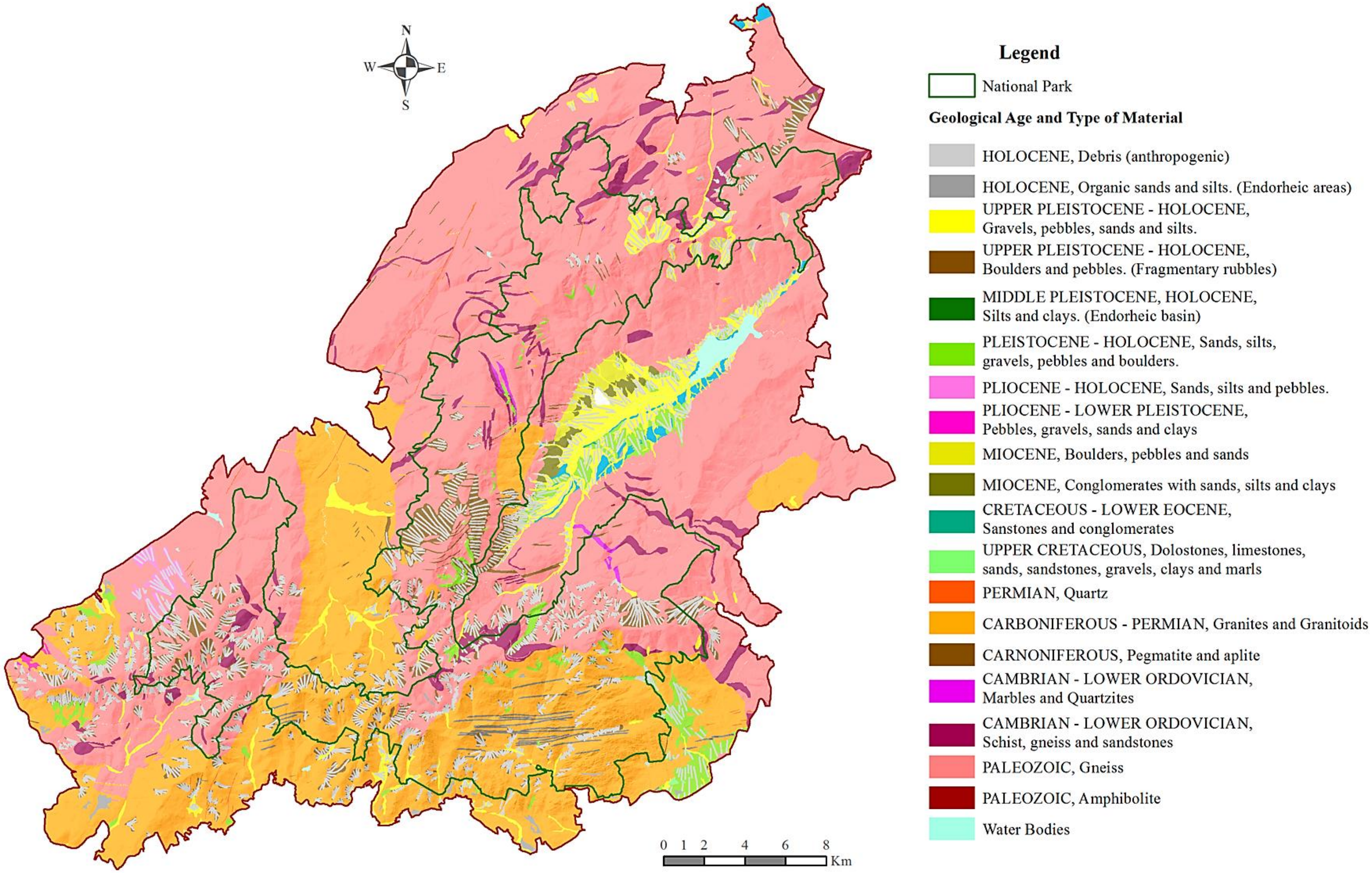


Figure 30. Geological Units: age and type of rocky material.

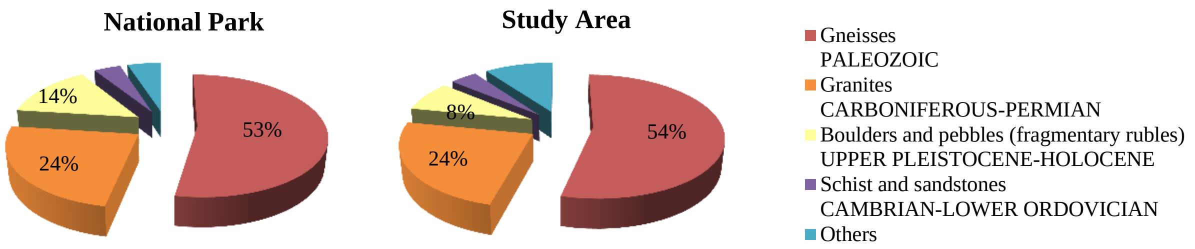


Figure 31. Distribution of the main types of geologic materials in the study area.

6.1.6 Land Uses

Both the territory as a whole and the National Park is practically covered by forest, scrub and grassland. The land uses map shows the most important covers in order of presence: coniferous forests, sclerophyllous vegetation, transitional woodland-scrub and natural grassland (figure 32 and table 11).

Eight per cent of the territory has suffered changes in land uses between 1990 and 2006, which confirm a recovery of vegetation cover, highlighting the following (figure 33 and table 5):

- 46%: from sclerophyllous vegetation to transitional woodland-scrub;
- 12%: from bare rocks to transitional woodland-scrub;
- 8%: from transitional woodland-scrub to coniferous forest;
- 7%: from bare rocks to sclerophyllous vegetation.

2006 / 1990	Continuous urban fabric	Discontinuous urban fabric	Sport and leisure facilities	Pastures	Broad-leaved forest	Coniferous forest	Natural grasslands	Sclerophyllous vegetation	Transitional woodland-scrub	Water bodies
Sport and leisure facilities								0,07		
Pastures	0,96	0,17			0,79		0,26			0,12
Agro-forestry areas		0,29								
Broad-leaved forest		0,19								0,05
Coniferous forest		0,17	0,79				0,42	1,52	1,36	
Natural grasslands		0,37			1,21	0,89		1,30	5,02	0,78
Sclerophyllous vegetation		0,60				1,64	0,66		45,65	
Transitional woodland-scrub						7,72	0,35			0,22
Bare rocks				0,11			0,49	6,80	12,16	2,19
Sparsely vegetated areas								1,47	2,09	

Table 5. Changes in land uses between 1990 and 2006.

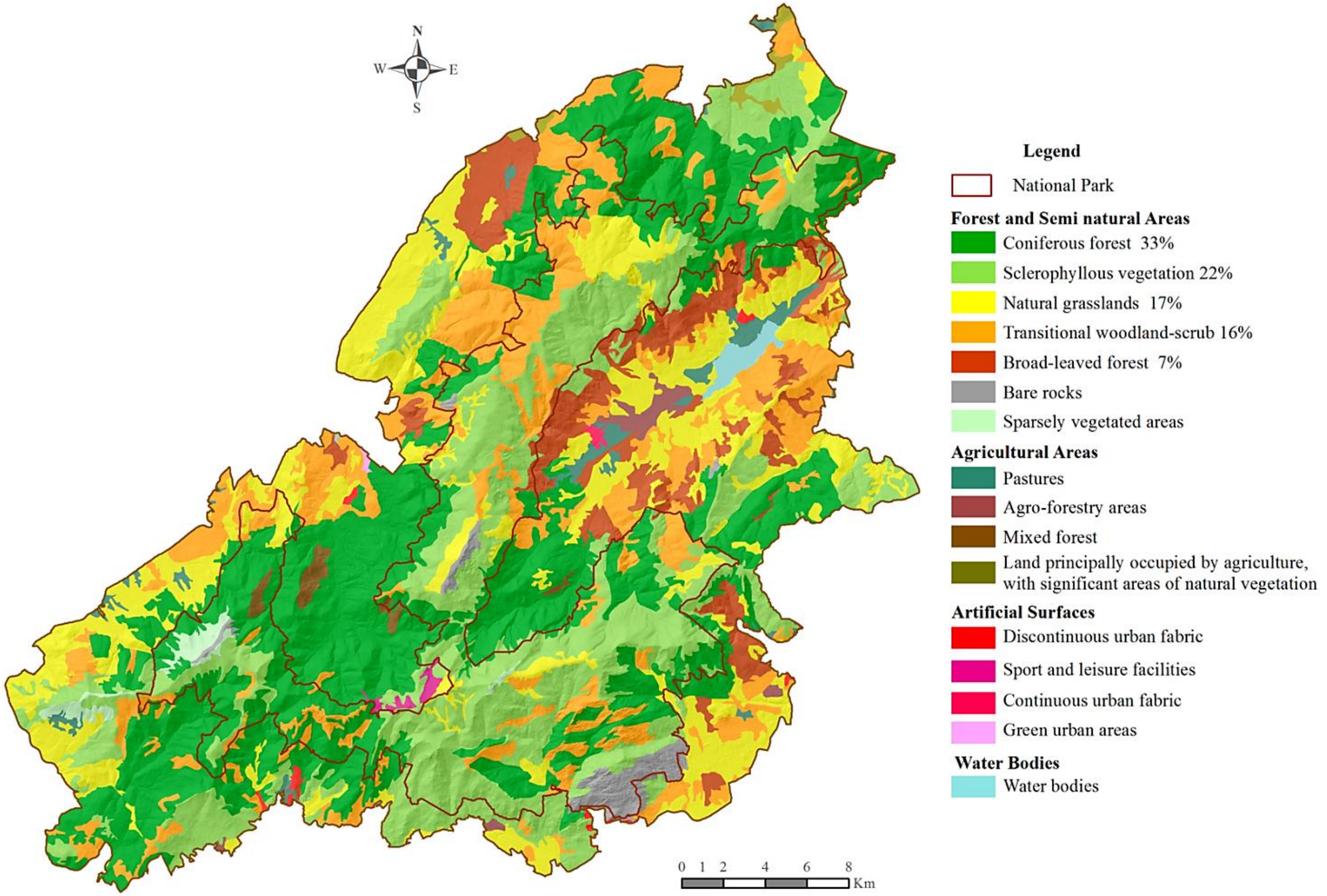


Figure 32. Map of Land Uses.

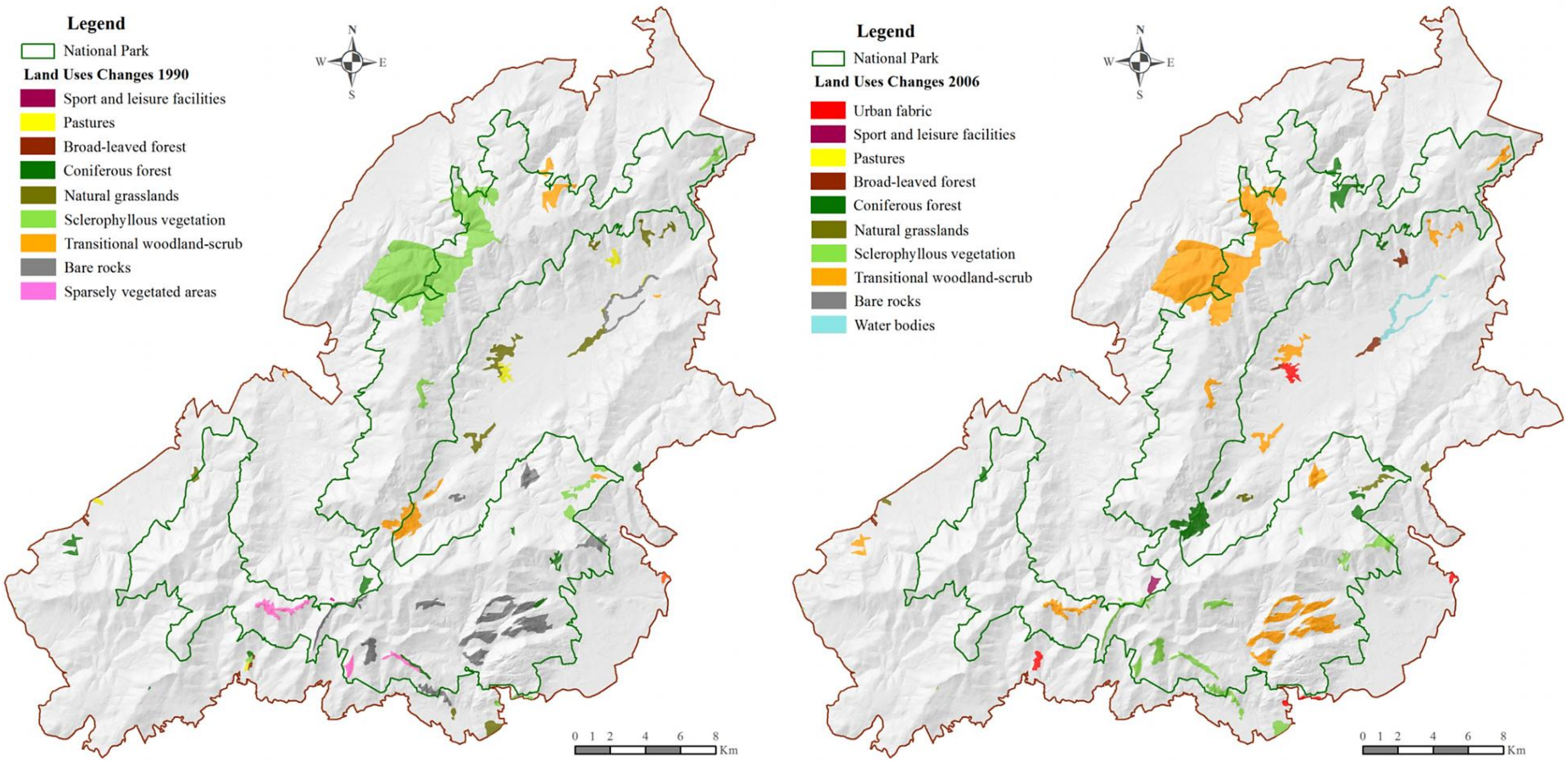


Figure 33. Maps of the changes in land uses between 1990 and 2006.

6.1.7 Protected Areas

Within the limits of the National Park there are other protected areas with different legal status (table 12):

- Natural Park '*Cumbre, Circo y Lagunas de Peñalara*'[5], whose lagoons are listed under the Ramsar Convention signed in 1971 (figure 34).
- Regional Park '*Cuenca Alta del Manzanares*'[6], and in addition, it was declared as Biosphere Reserve by UNESCO in 1993.
- Picturesque Site '*Pinar de Abantos y la Herrería*'[7].
- Natural Monument of National Interest '*Peña del Arcipreste de Hita*'.
- Natura 2000 Network[8] (figure 35):
  - Special Protection Areas (SPAs) for birds: '*Alto Lozoya*' and '*Sierra de Guadarrama*'.
  - Site of Community Importance (SCI): '*Cuenca del Río Lozoya y Sierra Norte*', '*Cuenca del río Manzanares*', '*Cuenca del río Guadarrama*', and '*Sierra del Guadarrama*'.

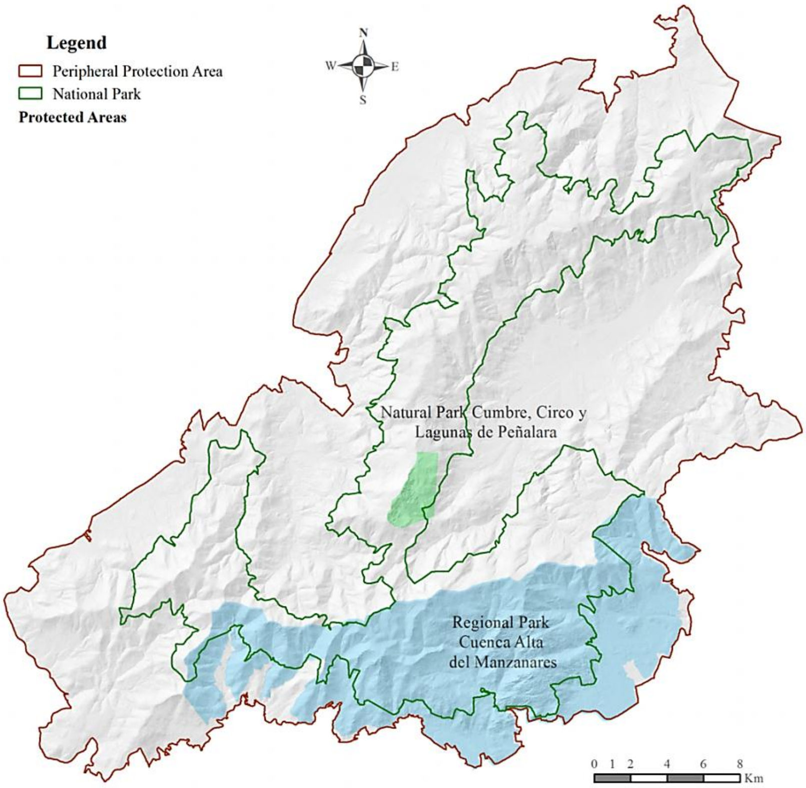


Figure 34. Map of Protected Areas.

[5] Law 6/1990 of May 10.
[6] Law 1/1985 of 23 January.
[7] Decree 2418/1961 of 16 November 1961
[8] Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora.

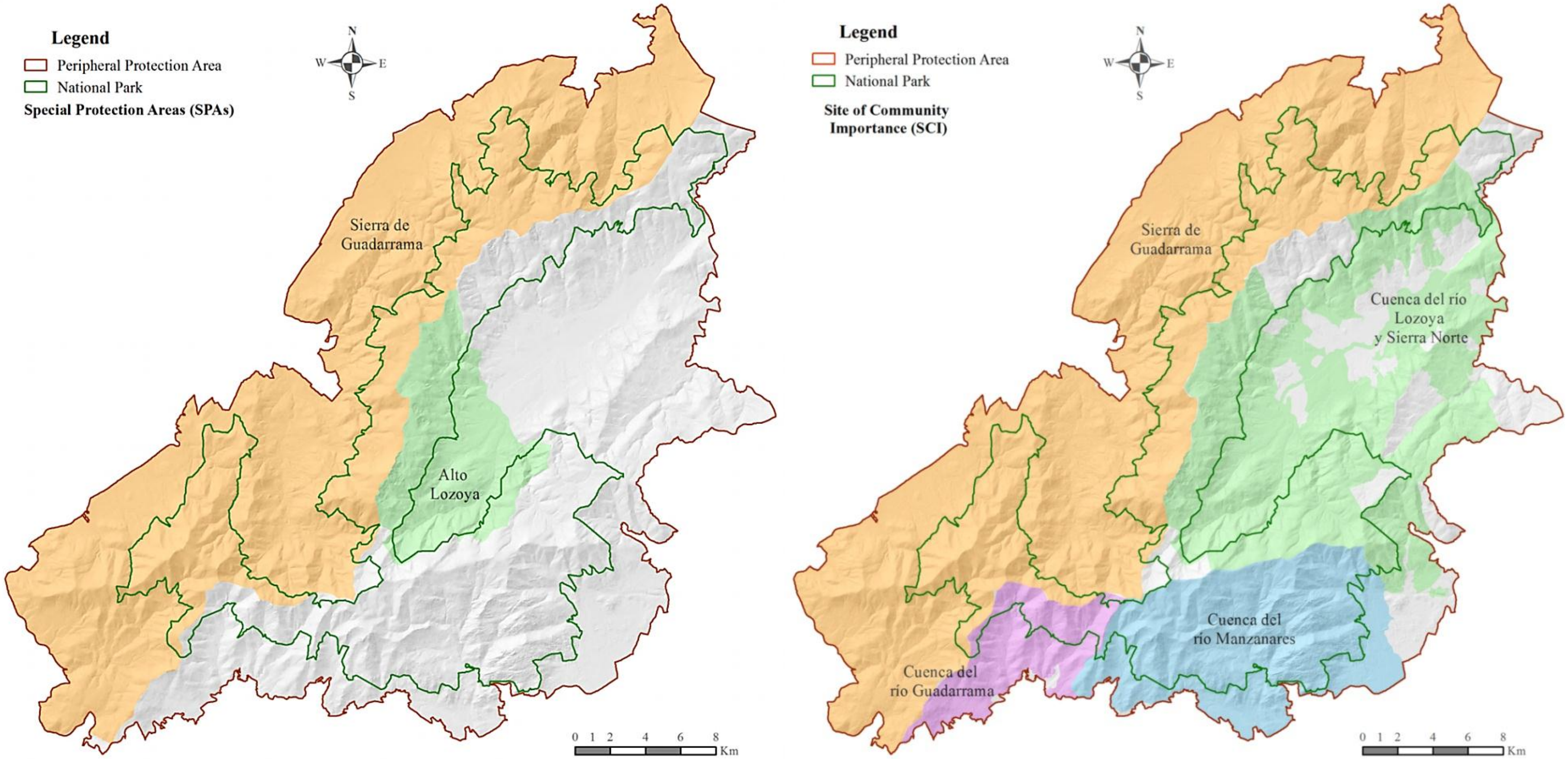


Figure 35. Maps of the Natura 2000 Network: Site of Community Importance (SCI) and Special Protection Areas (SPAs).

6.2 HUMAN ENVIRONMENT

6.2.1 Demographic Characteristics

The study area is located within the boundaries of 34 municipalities, which constitute the **area of socio-economic influence**[9] of the National Park created in order to contribute to the maintenance of protected areas, promote rural development and socio-economically compensate those affected. Nineteen of them belong to *Segovia* and fifteen to *Madrid* (table 13).

Twenty-eight of these municipalities provide territory to the National Park and peripheral protection area and the remaining six are just part of the peripheral protection area.

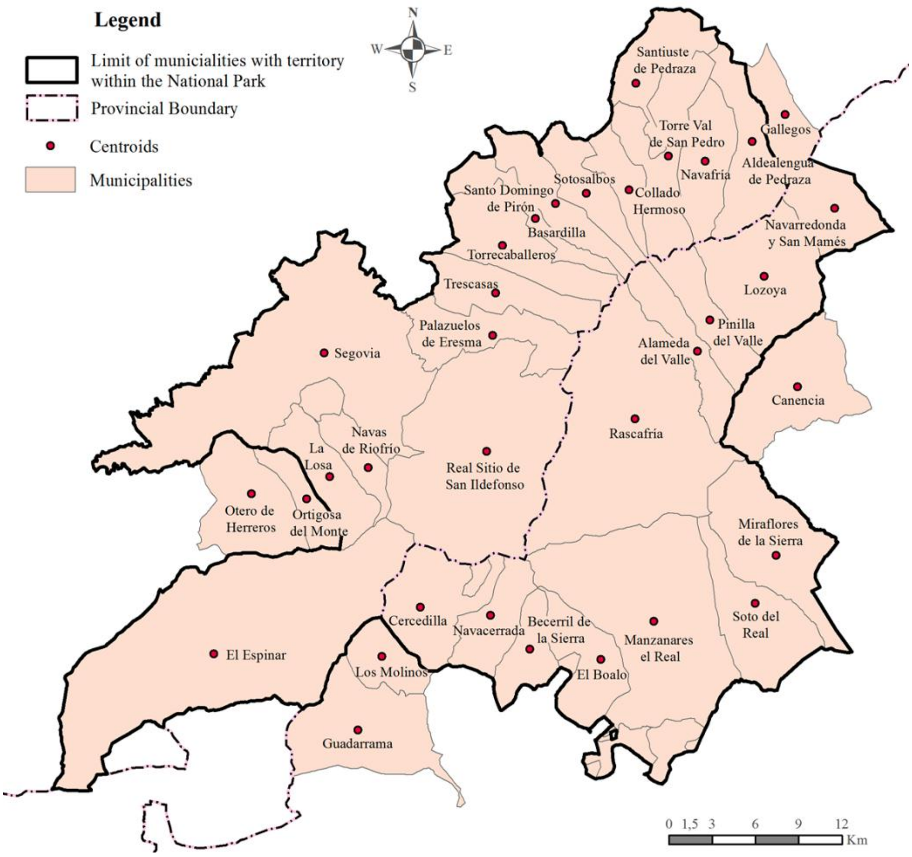


Figure 36. Map of Municipalities.

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[9] Article 99 of Law 9/1999, of May 26, Conservation of Nature.

It has a surface that it is extended in 1756 squares kilometres and characterized by its expansive dynamic in terms of both demographics and urbanism. The total population is 148997 inhabitants, being half men and half women, and the population density, that reflects the demographic pressure on the territory, is 68 inhabitants per square kilometre[10]. The population distribution by age group is as follows: 17% under 16, 67% aged 16 to 65 years and 16% over 65 years.

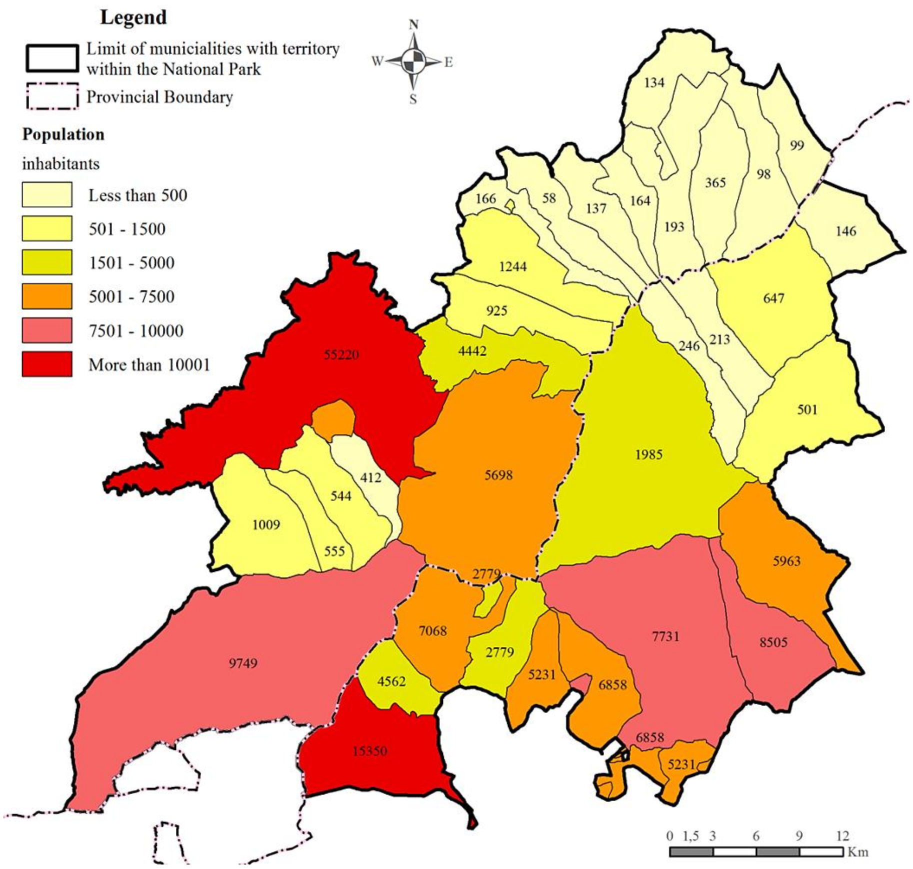

Figure 37. Map of the distribution of the Total Population.

There are great differences of occupation. In the case of municipalities situated in the Northeast, the population does not exceed five hundred inhabitants and the population density is very low, not overcoming ten inhabitants per square kilometre. While in the case of municipalities as *Segovia* (55220 inhabitants and 338 inhabitants per square kilometres) and *Guadarrama*, the population exceeds ten thousand

[10] Official population figures resulting from the municipal register of January 1, 2011 (updated January 13, 2012). Data Source: National Institute of Statistics.

inhabitants and the population density is greater than two hundred inhabitants per square kilometre. The village with the lowest population and population density is *Santo Domingo de Pirón*, with 58 inhabitants and 2,1 inhabitants per square kilometre, respectively.

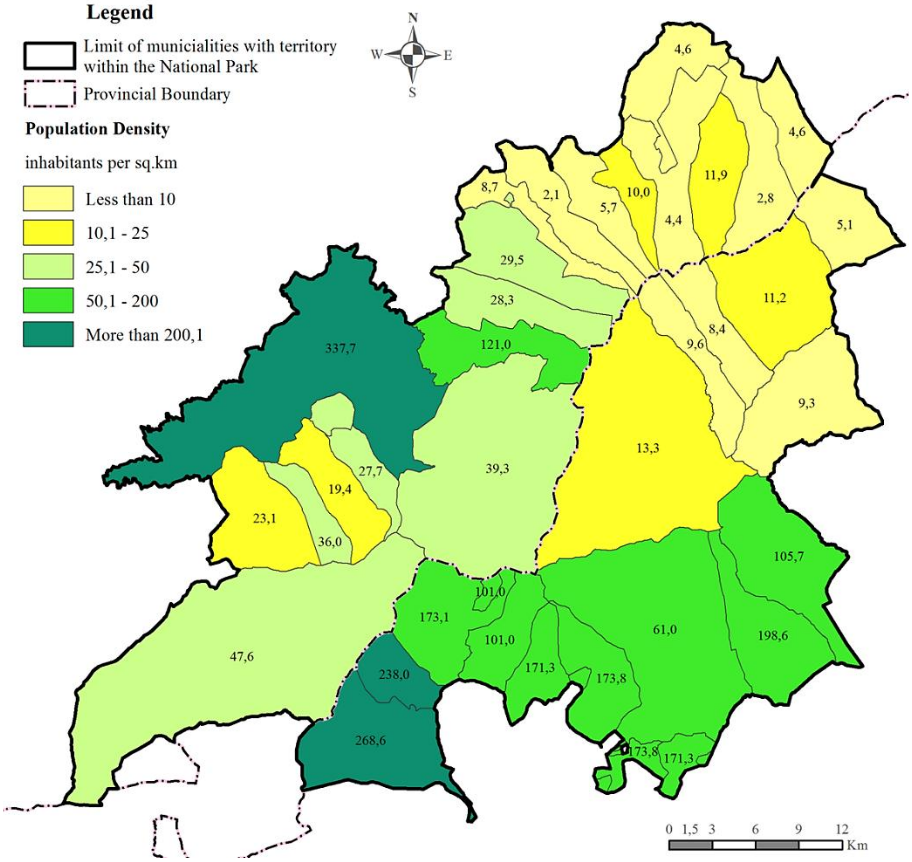

Figure 38. Population Density map.

6.2.2 Urban Areas and Transport Network

This territory is crossed by the regional road M-601 that connects *Madrid* to *Segovia*. The most important villages are situated along the secondary road M-604 (in the province of *Madrid*) or C-604 (in the province of *Segovia*), that elapses along the *Lozoya* Valley to *Puerto de Navacerrada*. The villages of *Lozoya,* the largest village in the area, and *Navafría* are linked by the road M-637/SG-612, and the villages of *Oteruelo del Valle* and *Miraflores de la Sierra* are linked by the M-611 that passes through *Puerto de la Morcuera*.

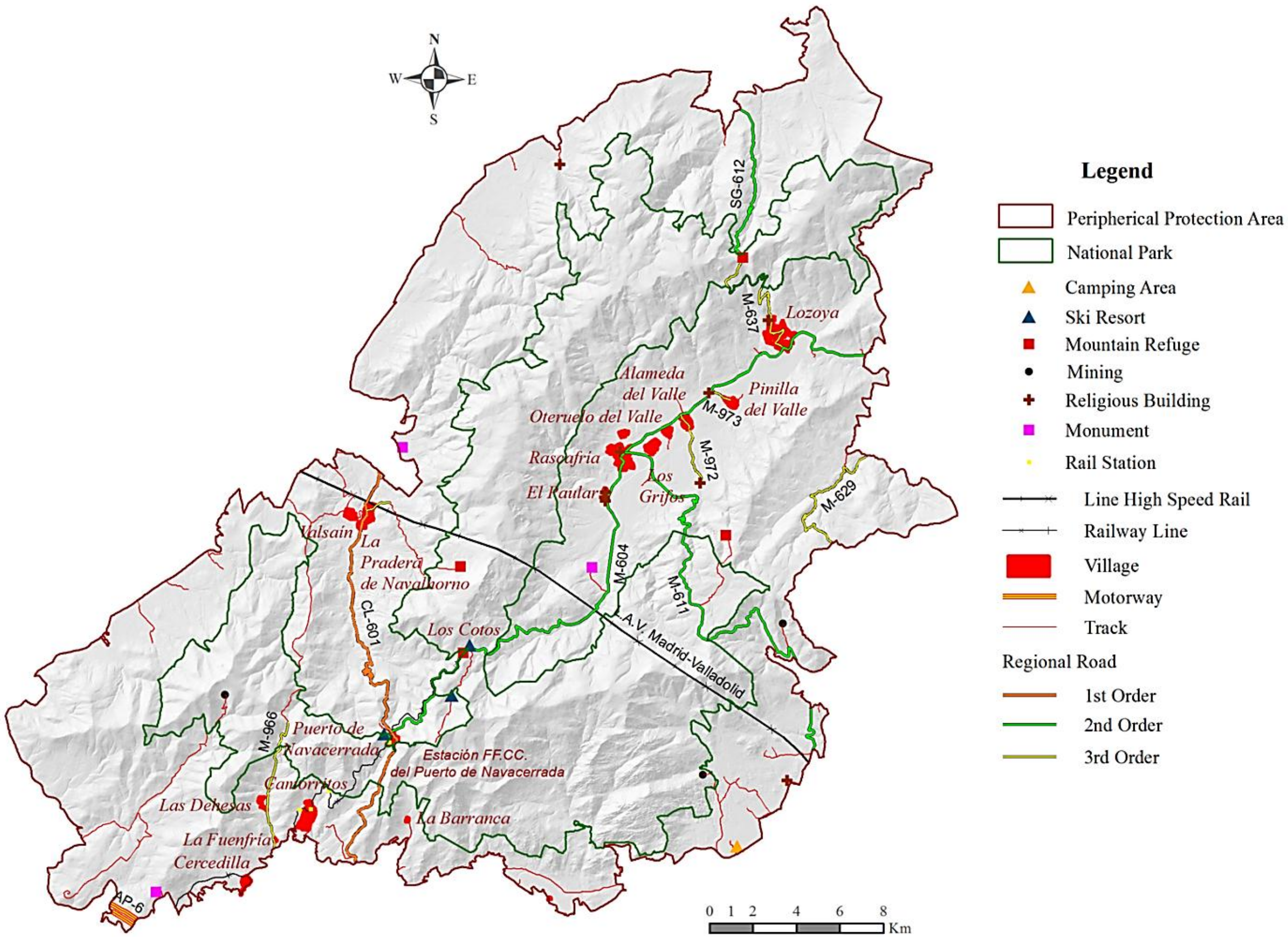

Figure 39. Map of Urban Areas and Transport Network.

The railway lines of high speed across the territory in SE-NW direction, connecting *Madrid* to the northern half of Spain. In addition, there is a line of narrow gauge railway that climbs from *Cercedilla* through *Puerto de Navacerrada* to reach *Puerto de Cotos*.

There is a strong pressure from urban centres around the National Park and its surroundings (figure 40).

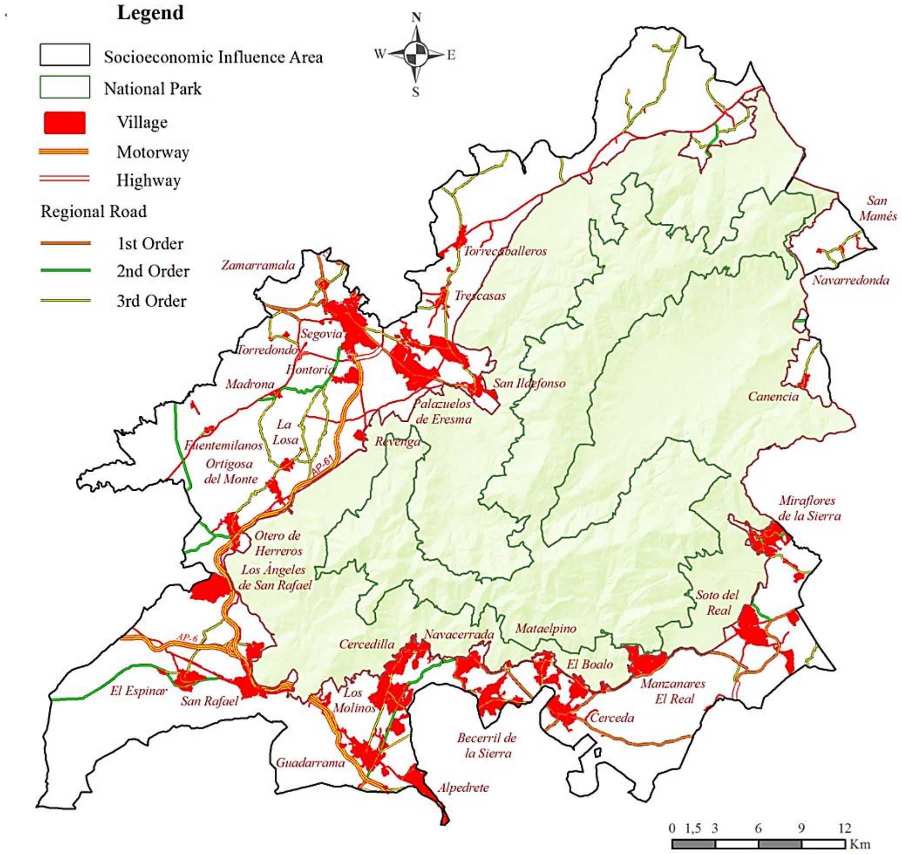

Figure 40. Map of Urban Areas and Transport Network around the National Park.

7. CONCLUSIONS

From the last decade, it has had a fast growing trend in the distribution and obtaining of geospatial data characterizing the physical and human environment of the earth surface. The use of this information encourages the development of new research to solve practical problems.

This research highlights the importance of using geospatial technologies as tools to the knowledge and study of the territory. Available today, Geographic Information Systems (GIS) play an important role for the progress of society.

The integration of spatial data into a Geographic Information System (GIS) allows for its analysis and processing, resulting in the cartography, whose purpose is to communicate the Geographic Information (GI) that characterizes the physical and human environment of the National Park and its surroundings, and favouring the knowledge and understanding of this territory. Without doubt an indepth analysis of territory would be a difficult task without the use of geospatial technologies and the geographic information associated with them.

Websites are one of the methods currently used to monitor and communicate the results of the solutions proposed by the GIS. A publicly available website is constructed http://www.geomundo.es, whose content is a comprehensive digital Atlas.

The educative digital Atlas of the National Park '*Las Cumbres de la Sierra de Guadarrama'* is the result of embracing the possibilities of geospatial technologies, together with Internet capacity as a medium for disseminating geographic information in map form. Publishing the Atlas on the Internet is invaluable to the general public, and is a way to share geographic information with others around the globe.

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ANNEXE 1: Description of different Types of Maps and Geospatial Data.

Visible Layers	Geometry	Attributes	Measurement Scale	A[1]	Scale/ Source[2]
Fig 41. Location map of the National Park in Europe.					1:30000000 WGS84
PPA	Polygon	-	-		-
Countries	Polygon	Name	Nominal		3
Fig 2. Situation map of the National Park between the provinces of Madrid and Segovia.					1:7000000 ETRS89
PPA	Polygon	-	-		-
Provinces	Polygon	Name	Nominal	x	1
Autonomous Communities	Polygon	Name	Nominal	x	1
Countries	Polygon	Name	Nominal	x	3
Fig 42. Administrative division into two provinces of the National Park and its peripheral protection area.					1:250000
NP	Polygon	-	-		-
PPA	Polygon	-	-		-
Provinces	Polygon	Name	Nominal	x	1
Fig 3. Map of situation and limits of the National Park and its peripheral protection area.					1:300000
NP	Polygon	-	-		-
PPA	Polygon	-	-		-
Orthophoto	Cell	-	-		19
Fig 4. Map of the Network of Spanish National Parks.					1:6000000 / 1:5000000 ETRS89
NP	Polygon	-	-		-
Protected Areas: parks	Polygon	Name	Nominal	x	5
Autonomous Communities	Polygon	Name	Nominal	x	1
Countries	Polygon	Name	Nominal	x	3
Fig 7. Situation Maps of weather stations from which are obtained rainfall and temperature data.					
NP	Polygon	-	-		-
PPA	Polygon	-	-		-
Weather Stations: Rainfall	Polygon	-	-		-
Weather Stations: Temperature	Polygon	-	-		-
Fig 8. Grid Cells of National Cartographic Base (BCN25) at 1:25000 scale.					-
PPA, NP, Municipalities	Polygon	-	-		-
Distribution of sheets at scale 1:25.000	Polygon	Number	-	x	10
Fig 15. Topographic Map.					1:250000
Elevation model that gives a description of the mountain ranges and higher peaks.					
NP	Polygon	-	-		-
PPA	Polygon	-	-		-
Geodesic Vertices	Multipoint	Height - Name	-	x	9
Mountain Ranges	Polyline	Name	-	x	9
Hillshade	Cell	-	-		8
Fig 16. Distribution map of Heights.					1:250000
Isopleth map, representing the distribution of the height in intervals.					Quantitative
NP	Polygon	-	-		-
PPA	Polygon	-	-		-
Contour Lines	Polyline	-	-	x	9
Distribution of heights	Polygon	Height	Interval		8
Fig 17. Slopes Map.					1:250000
The mapping of slopes.					Quantitative
NP	Polygon	-	-		-
PPA	Polygon	-	-		-
Slopes	Cell	Slope	Interval		8
Hillshade	Cell	-	-		8

Visible Layers	Geometry	Attributes	Measurement Scale	A[1]	Scale/ Source[2]
Fig 18. Map of the Hydrographic Network.					1:250000
The mapping of drainage, including river basin and water bodies like rivers, lagoons and reservoirs.					Qualitative
NP	Polygon	-	-		-
PPA	Polygon	-	-		-
Dams	Polyline	-	-		9
Rivers	Polyline	Name Category	Nominal	x	9
Lagoons	Polygon	Name	-	x	9
Reservoirs	Polygon	Name	-	x	9
River Basin	Polygon	-	-		8
Main Watershed	Polyline	-	-		8
Hillshade	Cell	-	-		8
Fig 19. Distribution map of Annual Rainfall.					1:250000
Isohyets map, representing the spatial distribution of the amount of rainfall in intervals.					Quantitative
NP	Polygon	-	-		-
PPA	Polygon	-	-		-
Rainfall	Polygon	Rainfall	Interval		-
Hillshade	Cell	-	-		8
Fig 20. Distribution map of Average Annual Temperature.					1:250000
Isotherm map, representing the spatial distribution of the temperature in intervals.					Quantitative
NP	Polygon	-	-		-
PPA	Polygon	-	-		-
Temperature	Polygon	Temperature	Interval		-
Hillshade	Cell	-	-		8
Fig 21. Map of Potential Vegetation and Altitudinal Zonation.					1:250000
Qualitative map that identifies the potential vegetation and its altitudinal zonation.					Qualitative
NP	Polygon	-	-		-
PPA	Polygon	-	-		-
Phytoclimatic Region	Polygon	Type	Nominal		12
Potential Vegetation	Polygon	Type	Nominal		11
Hillshade	Cell	-	-		8
Fig 22. Map of Vegetation Types.					1:250000
Complete coverage of polygons classified according to the vegetation cover on the land.					Qualitative
NP	Polygon	-	-		-
PPA	Polygon	-	-		-
Vegetation Type	Polygon	Type	Nominal		14
Hillshade	Cell	-	-		8
Fig 23. Map of Dominant Species or Formations.					1:250000
Spatial identification of dominant vegetal species or formations, whose area comprises more than 1% of the total one.					Qualitative
NP	Polygon	-	-		-
PPA	Polygon	-	-		-
Dominant Species or Formations	Polygon	Description	Nominal		14
Hillshade	Cell	-	-		8
Fig 24. Map of the Vegetal Stratum.					1:250000
Coverage of polygons classified according to the vegetal stratum.					Qualitative
NP	Polygon	-	-		-
PPA	Polygon	-	-		-
Vegetal Stratum	Polygon	Type	Nominal		14
Hillshade	Cell	-	-		8

Visible Layers	Geometry	Attributes	Measurement Scale	A[1]	Scale/ Source[2]
Fig 25. Map of Agricultural Crops and Forest Land.					1:250000
Coverage of polygons describing agricultural crops and forest land.					Qualitative
NP	Polygon	-	-		-
PPA	Polygon	-	-		-
Agricultural Crops and Forest Land	Polygon	Type	Nominal		13
Hillshade	Cell	-	-		8
Fig 26. Map of Dominant Forest Species or Formations.					1:250000
Spatial identification of dominant forest species.					Qualitative
NP	Polygon	-	-		-
PPA	Polygon	-	-		-
Dominant Forest Species	Polygon	Description	Nominal		13
Hillshade	Cell	-	-		8
Fig 28. Map of Habitats.					1:250000
Habitats mapping identifying the types of habitats.					Qualitative
NP	Polygon	-	-		-
PPA	Polygon	-	-		-
Habitats	Polygon	Type	Nominal		15
Hillshade	Cell	-			8
Fig 29. Map of Conservation Status of the Habitats.					1:250000
Mapping of conservation status of the habitats.					Quantitative
NP	Polygon	-	-		-
PPA	Polygon	-	-		-
Conservation Status	Polygon	Category	Ordinal		15
Hillshade	Cell	-	-		8
Fig 30. Map of Geological Units: age and type of rocky material.					1:250000
Continuous geological mapping, classified according to the geological age and rock type.					Qualitative
NP	Polygon	-	-		-
PPA	Polygon	-	-		-
Geology	Polygon	Geological age Rock type	Nominal		16
Hillshade	Cell	-	-		8
Fig 32. Map of Land Uses (Corine Land Cover 2006).					1:250000
Coverage of polygons of the current land uses.					Qualitative
NP	Polygon	-	-		-
PPA	Polygon	-	-		-
Land Cover (CLC) 2006	Polygon	Type	Nominal		17
Hillshade	Cell	-	-		8
Fig 33. Maps of the Changes in the Land Uses between 1990 and 2006.					1:250000
Identification of the changes occurred on land uses between 1990 and 2006.					Qualitative
NP	Polygon	-	-		-
PPA	Polygon	-	-		-
Changes Land Cover 1990-2006	Polygon	Code90 - Code06	Nominal		17
Hillshade	Cell	-	-		8
Fig 34. Maps of Protected areas.					1:250000
Identification of the protected areas with other legal status.					Qualitative
NP	Polygon	-	-		-
PPA	Polygon	-	-		-
Protected Areas: parks	Polygon	Name	Nominal	x	5
Hillshade	Cell	-	-		8

Visible Layers	Geometry	Attributes	Measurement Scale	A[1]	Scale/ Source[2]
Fig 35. Maps of the Nature 2000 Network: Site of Community Importance (SCI) and Special Protection Areas (SPAs).					1:250000
Identification of Site of Community Importance (SCI) and Special Protection Areas (SPAs) included in Nature 2000 Network.					
NP	Polygon	-	-		-
PPA	Polygon	-	-		-
Special Protection Areas (SPAs)	Polygon	Name	Nominal	x	4
Site of Community Importance (SCI)	Polygon	Name	Nominal	x	4
Hillshade	Cell	-	-		8
Fig 36.Map of Municipalities.					1:350000
Identification of municipalities which constitute the area of socio-economic influence of the National Park.					
NP	Polygon	-	-		-
PPA	Polygon	-	-		-
Centroids	Point	-	-		1
Municipalities NP	Polygon	-	-		1
Municipalities	Polygon	Name	-	x	1
Provinces	Polygon	-	-		1
Fig 37. Distribution Map of the Population.					1:350000
Choropleth map representing the total population distribution.					Quantitative
NP	Polygon	-	-		-
PPA	Polygon	-	-		-
Municipalities	Polygon	Total population	Interval	x	1
Centroids	Point	-	-		9
Municipalities NP	Polygon	-	-		1
Provinces	Polygon	-	-		1
Fig 38. Population Density map.					1:350000
Choropleth map representing the population density distribution.					Quantitative
NP	Polygon	-	-		-
PPA	Polygon	-	-		-
Municipalities	Polygon	Population Density	Interval	x	1
Municipalities NP	Polygon	-	-		1
Provinces	Polygon	-	-		1
Fig 39. Map of Urban Areas and Transport Network.					1:250000
Nature and location of urban areas, major roads and railways.					Qualitative
NP	Polygon	-	-		-
PPA	Polygon	-	-		-
Place of interest	Multipoint	-	-		9
Accommodation	Multipoint	-	-		9
Mining	Multipoint	-	-		9
Villages	Point	Name	-	x	9
Blocks	Polygon	-	-		18
Motorway	Polyline	Name	-	x	9
Regional Roads	Polyline	Name Order	Ordinal	x	9
Tracks	Polyline	-	-		9
Railway Stations	Multipoint	Name	-	x	9
Railway Line	Polyline	Name	-	x	9
Line High Speed Rail	Polyline	Name	-	x	9

Visible Layers	Geometry	Attributes	Measurement Scale	A[1]	Scale/ Source[2]
Fig 40. Map of Urban Areas and Transport Network around the National Park.					1:350000
Nature and location of urban areas, major roads outside the peripheral protection area.					Qualitative
NP	Polygon	-	-		-
PPA	Polygon	-	-		-
Villages	Point	Name	-	x	9
Blocks	Polygon	-	-		18
Dual Carriageway	Polyline	Name	-	x	9
Motorway	Polyline	Name	-	x	9
Regional Roads	Polyline	Name Order	Ordinal	x	9
Tracks	Polyline	-	-		9
Railway Line	Polyline	-	-		9
Line High Speed Rail	Polyline	-	-		9

Notes:
[1] Annotations
[2] Source according to the table 1
PPA: Peripheral Protection Area
NP: National Park

ANNEXE 2: Tables of Results.

Table 6. Parameters that define the European Terrestrial Reference System 1989 (ETRS89).

Geographic Coordinate System	GCS_ETRS_1989
Angular Unit	Degree (0,0174532925199433)
Prime Meridian	Greenwich (0,0)
Datum	D_ETRS_1989 European Terrestrial Reference System 1989
Spheroid	GRS_1980
Semimajor Axis	6378137,0
Semiminor Axis	6356752,314140356
Inverse Flattening	298,257222101

Table 7. Distribution of Heights in the National Park (NP) and the Peripheral Protection Area (PPA).

Elevation	**NP %**	**PPA %**	**Total %**
800 – 1200		19	13
900 – 1200	2		
1200 – 1500	14	51	38
1500 – 1800	36	27	30
1800 – 2100	42	3	17
+ 2100	6	0	2

Table 8. Distribution of Slopes in the National Park.

Slope	**%**
5 – 10	13
10 – 15	17
15 – 20	23
20 – 25	23
25 – 30	15
+ 30	9

Table 9. Distribution of Vegetation Types and Heights in the study area.

NP (%)	**Vegetation Type**	**Height (m)**	**%**	**Species or Formations**	**%**
14	**Rocky outcrops or compact lava**	924-2427	6	Rocky desert – *Quercus pyrenaica – Quercus ilex rotundifolia*	33
				Rocky desert – *Cytisus laurifolious – Cytisus ladanifer*	21
30	**High Mountain**	1231-2410	13	*Cytisus purgans - Juniperus communis alpina*	70
33	**Taiga**	1054-2206	23	*Pinus sylvestris*	57
				Pinus sylvestris - Cytisus purgans	12
21	**Sub-Sclerophyllous Forest**	894-2145	51	*Pinus sylvestris*	30
				Quercus pyrenaica	16
				Quercus pyrenaica – Pinus sylvestris	5
				Quercus pyrenaica - grassland	4
0,7	**Sclerophyllous forest**	894-1539	1		
1	**Gravel areas, stony areas**	1486-2194	0,5		
0,002	**Hydrophyllum vegetation**	900-1460	4	Swath meadow – Grassland - *Fraxinus angustifolia*	29
0,3	**Other**		1,5		

Table 10. Distribution of Habitats and Heights in the study area.

	Study Area		NP
	%	Height (m)	%
3. FRESHWATER HABITATS			
31. Standing water			
3150 Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition* – type vegetation	0	1137-1475	0
3160 Natural dystrophic lakes and ponds	0	1088-1089	-
3170 * Mediterranean temporary ponds	0,02	1073-2094	-
32. Running water – sections of water courses with natural or semi-natural dynamics (minor, average and major beds) where the water quality shows no significant deterioration			
3260 Water courses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation	0	1038-1403	-
4. TEMPERATE HEATH AND SCRUB			
4030 European dry heaths	0,8	1162-1742	2,1
4090 Endemic oro-Mediterranean heaths with gorse	16,1	980-1909	1,4
5. SCLEROPHYLLOUS SCRUB (MATORRAL)			
51. Sub-Mediterranean and temperate scrub			
5120 Mountain *Cytisus purgans* formations	51,3	1206-2427	75,2
52. Mediterranean arborescent matorral			
5210 Arborescent matorral with *Juniperus* spp.	0,006	939-1328	-
6. NATURAL AND SEMI-NATURAL GRASSLAND FORMATIONS			
61. Natural grasslands			
6160 Oro-Iberian *Festuca indigesta* grasslands	2,4	926-2379	4,5
62. Semi-natural dry grasslands and scrubland facies			
6220 * Pseudo-steppe with grasses and annuals of the *Thero-Brachypodietea*	6,1	909-1616	1,1
63. Sclerophillous grazed forests (dehesas)			
6310 Dehesas with evergreen *Quercus* spp.	0,2	1103-1502	-
65. Mesophile grasslands			
6510 Lowland hay meadows (*Alopecurus pratensis, Sanguisorba officinalis*)	0,3	1091-1205	-
7. RAISED BOGS AND MIRES AND FENS			
71. Sphagnum acid bogs			
7130 Blanket bogs (* if active bog)	0,0008	1662-1812	0,002
7150 Depressions on peat substrates of the *Rhynchosporion*	0	1173-1173	0
8. ROCKY HABITATS AND CAVES			
81. Scree			
8130 Western Mediterranean and thermophilous scree	1,5	1389-2427	3,0
82. Rocky slopes with chasmophytic vegetation			
8210 Calcareous rocky slopes with chasmophytic vegetation	0,0008	1097-1115	3,0
8220 Siliceous rocky slopes with chasmophytic vegetation	1,5	1144-2335	-
8230 Siliceous rock with pioneer vegetation of the *Sedo-Scleranthion* or of the *Sedo albi-Veronicion dillenii*	3,1	937-2264	7,3

9. FORESTS

91. Forests of Temperate Europe			
91B0 Thermophilous *Fraxinus angustifolia* woods	1,7	894-1483	-
92. Mediterranean deciduous forests			
9230 Galicio-Portuguese oak woods with *Quercus robur* and *Quercus pirenaica*	12, 7	896-1735	1,3
9240 *Quercus faginea* and *Quercus canariensis* Iberian woods	0,02	920-1229	-
92A0 Salix alba and Populus alba galleries	1,4	932-1919	0,7
93. Mediterranean sclerophyllous forests			
9340 *Quercus ilex* and *Quercus rotundifolia* forests	0,9	1130-1502	0,3
9380 Forests of *Ilex aquifolium*	0,04	1219-1849	-
95. Mediterranean and Macaronesian mountainous coniferous forests			
9560 * Endemic forests with *Juniperus* spp.	0,02	1185-1330	-
*Priority species or habitats. A zero value means that the area covers equal to or less than 0.00001%.			

Table 11. Distribution of Land Uses in the study area.

			PN	PPA
Level 1	**Level 2**	**Level 3**	**Area** (%)	
Artificial Surfaces	Urban Fabric	Continuous urban fabric	0,07	-
		Discontinuous urban fabric	0,21	-
	Industrial, commercial, and transport units	Road and rail networks and associated land	0,01	-
	Mine, dump and construction sites	Construction sites	0,01	-
	Artificial, non-agricultural vegetated areas	Green urban areas	0,03	-
		Sport and leisure facilities	0,20	0,29
Agricultural areas	Pastures	Pastures	1,36	-
	Heterogeous agricultural areas	Land principally occupied by agriculture, with significant areas of natural vegetation	0,38	-
		Agro-forestry areas	0,58	-
Forest and semi natural areas	Forest	Broad-leaved forest	6,51	4,06
		Coniferous forest	33,25	42,28
		Mixed forest	0,50	0,04
	Scrub and/or herbaceous vegetation associations	Natural grasslands	16,50	13,08
		Sclerophyllous vegetation	22,13	24,73
		Transitional woodland-scrub	15,86	13,15
	Open spaces with little or no vegetation	Bare rocks	1,37	1,77
		Sparsely vegetated areas	0,67	0,57
Water bodies	Inland waters	Water Bodies	0,46	-

Table 12. Percentage of surface covers by other protected area within the limits of the National Park.

Protection	Name	%
ZEPAs	Alto Lozoya	100
	Sierra de Guadarrama	65
LICs	Cuenca del Río Lozoya y Sierra Norte	50
	Cuenca del río Manzanares	20
	Cuenca del río Guadarrrama	14
	Sierra del Guadarrama	65
Natural Park	Cumbre, Circo y Lagunas de Peñalara	100
Regional Park	Cuenca Alta del Manzanares	36

Table 13. Municipalities included in the Area of Socio-Economic Influence of the National Park, and livestock and agricultural region to which they belong.

Municipality	Livestock Regions	Agricultural Regions	Municipality	Livestock Regions	Agricultural Regions
MADRID			**SEGOVIA**		
Alameda del Valle	Buitrago	Lozoya Somosierra	El Espinar	Villacastín	Segovia
Canencia			Santiuste de Pedraza	Cantalejo	
Lozoya			Aldealengua de Pedraza	Segovia	
Navarredonda y San Mamés			Basardilla		
Pinilla del Valle			Collado Hermoso		
Rascafría			Gallegos		
Miraflores de la Sierra	Colmenar Viejo		La Losa		
Soto del Real			Navafría		
Becerril de la Sierra		Guadarrama	Otero de Herreros		
El Boalo			Palazuelos de Eresma		
Manzanares el Real			San Ildefonso		
Cercedilla	El Escorial		Santo Domingo de Pirón		
Guadarrama			Segovia		
Los Molinos			Sotosalbos		
Navacerrada			Torrecaballeros		
			Torre Val de San Pedro		
			Tres Casas		
			Ortigosa del monte		
			Navas de Riofrío		

ANNEXE 2: Maps.

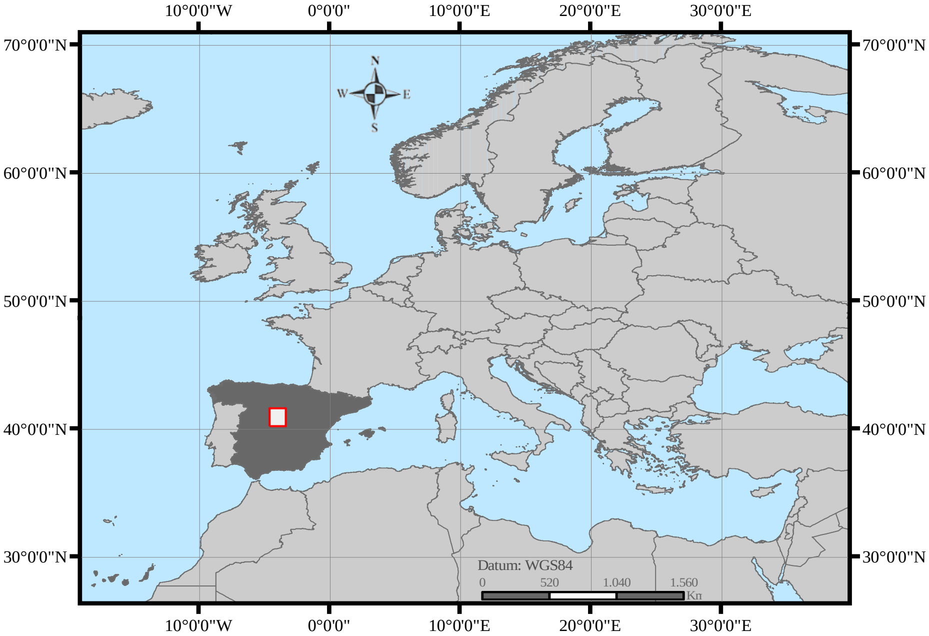

Figure 41. Location map of the National Park in Europe.

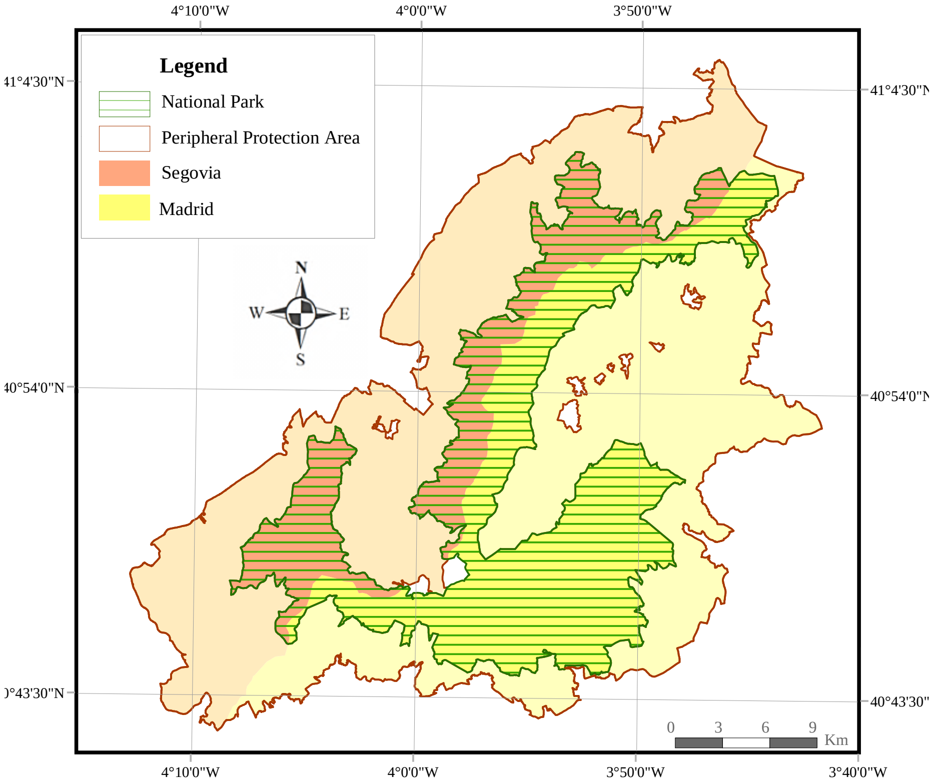

Figure 42. Map of the study area showing, the administrative division into two provinces.